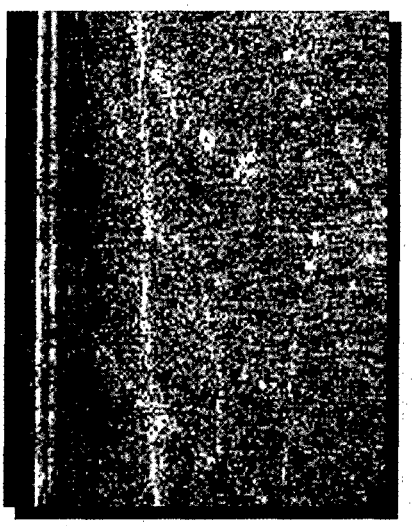
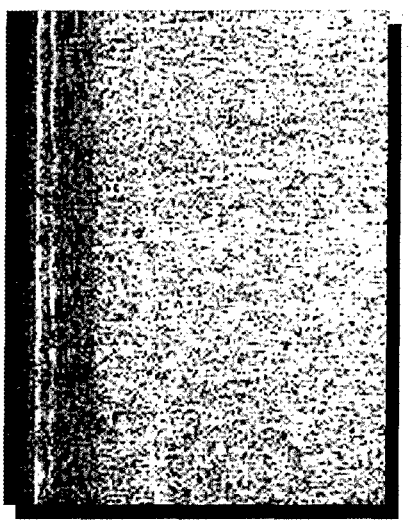
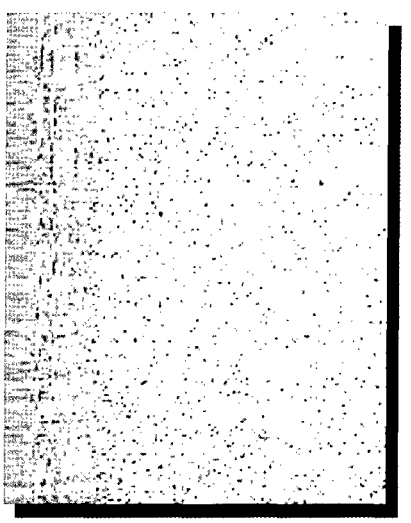
1994 Annual Report

IDA

Institute for Defense Analyses







Cover: Imagery of Arizona desert near Yuma collected from an airborne synthetic aperture radar. As part of the image formation process, the radar data were filtered with signal processing techniques developed at IDA to remove noise caused by broadcast radio and TV.

Inside cover: Successive stages of the filtering process, starting at the bottom with the original noise contaminated image.

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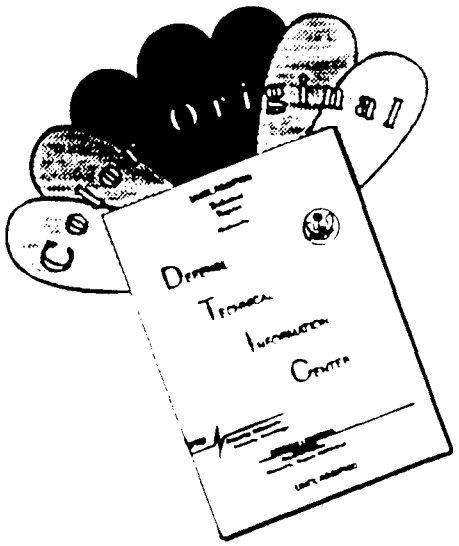

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THE INSTITUTE

The Institute for Defense Analyses is a federally funded research and development center established to assist the Office of the Secretary of Defense, the Joint Staff, the Unified Commands and Defense Agencies in addressing important national security issues, particularly those requiring scientific and technical expertise. IDA also conducts related research for other government agencies on national problems for which the Institute's skills and expertise are especially suited.

MESSAGE FROM THE PRESIDENT

Constant changes in the national and global environment can challenge the fundamental mission of an institution. A useful test for the institution — whether governmental, commercial, or non-profit — can often be the question: "What business are we in?" Where yesterday's answer that worked with yesterday's situation does not work today, there can be intense pressures to re-invent or re-engineer the institution. Many institutions are in the midst of that painful process today because they failed to evolve with their customers' needs. IDA's management, from supervisors to the Board of Trustees, has long made a practice of frequently and seriously addressing that question. This practice comes not from self-doubt, but from IDA's continuing commitment to remain relentlessly relevant to the needs of our sponsors and the needs of national security.

While every successful enterprise pays attention to how well it meets its customers' needs, this is a particularly important responsibility at IDA. As a Federally Funded Research and Development Center dedicated to serving the Department of Defense, IDA maintains a long-term, strategic relationship with its sponsors. The terms and conditions of that special relationship define our enduring reason for being and our enduring characteristics. They also provide the basis for constant evolution in capabilities to continue our proven effectiveness in supporting national security leaders.

IDA's basic purpose is to support the mission and operations of its sponsoring offices. IDA provides that support by combining private sector management flexibility with high-quality analyses and technical advice, fully informed by broad access to information and in-depth knowledge of Defense problems. At the same time, both we and our sponsors recognize that our value to the Department depends on our objectivity and independence and freedom from institutional biases. To carry out our mission, we agree to special terms and conditions well beyond those that would be acceptable to most other private enterprises. Those terms and conditions are intentionally designed to provide a very high degree of trust and freedom from real or perceived conflicts of interest and to provide an intense and dedicated focus on our sponsor's needs.

To that end, we forgo any business relationships with for-profit enterprises, and we do not compete with for-profit firms. We focus our attention on the IDA core competencies important to our DoD sponsors. We maintain a research staff with extraordinarily high competency in these areas. We follow personnel policies that provide the stability needed for corporate memory and a deep

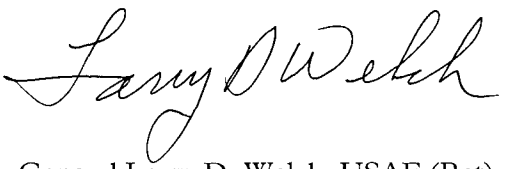
Larry D. Welch, President (right) and W. Jarvis Moody, Chairman

understanding of our sponsors' missions and operations. At the same time, we provide continuing professional growth opportunities to existing staff and recruit bright new researchers to maintain state-of-the-art currency in our core competencies. We maintain a completely open relationship and open communication with our sponsors. That openness provides confidence that we are working on the right problems and evolving in directions that best serve our mission.

There are a number of important measures of how well this special relationship and IDA's effectiveness are holding up in this period of changing needs and demands. One such measure is the constantly expanding demand for IDA support. Another is the frequency with which DoD turns to IDA for analytical support on the most difficult and controversial defense decisions. Still another is the strong support expressed by senior DoD sponsors in testimony to the recent Defense Science Board Task Force on "The Role of Federally Funded Research and Development Centers in the Mission of the Department of Defense."

The basis of the DoD-IDA special relationship is sound and relevant today. We frequently examine our direction and make needed course corrections while adhering to our fundamental purposes. Even as the national security environment changes rapidly, we continue to understand the "business we are in" and radical re-invention or re-engineering is not needed. Our sponsors continue to call for the high-quality work that IDA provides in areas of core competency. We are playing an appropriate and important role in helping DoD respond to the changing national security environment.

The pages that follow provide an overview of some of IDA's work. IDA's work divides into five core areas: systems evaluation, technology assessments, strategy and force assessments, resource and support analyses, and high performance computing and communications. For ease of reader understanding, however, we have treated our test and evaluation, advanced simulation, and information systems and technology research areas, which draw on several areas of core competency, as separate sections.



General Larry D. Welch, USAF (Ret)
President

RESEARCH OVERVIEW

IDA's yearly program of research is a mixture of continuing analyses that address enduring problems and new starts in response to sponsor requirements. We categorize our work into five core areas: systems evaluation, technology assessments, strategy and force assessments, resource and support analyses, and high performance computing and communications. We treat our test and evaluation, information systems and technologies, and advanced simulation here as separate sections as these also draw on IDA's core competency. Overviews of each of these, with brief descriptions of representative studies, are given here.

SYSTEMS EVALUATION

A major focus of IDA's work is systems evaluation and the use of cost-effectiveness studies to assist the government's decision-making process. With the shift of the threat from the Warsaw Pact to geographically diverse regional conflict, new issues and more complex challenges are facing DoD's senior leadership. Every major area of defense planning and acquisition is being fundamentally reevaluated. IDA is closely involved in the study of many of the systems, especially those in the broad areas of strategic and tactical weapons systems, theater missile defense, command, control, and communications systems, and space systems.

Strategic and Tactical Weapons Systems

Assessments of Bombers in Conventional Conflicts

The long-range heavy bomber force is one leg of our nuclear deterrent, and it is also an important asset in conventional conflicts. Today, the heavy bomber force comprises three different aircraft: the B-52H, in service for over 30 years, the B-1B, and the B-2. The B-52H and B-2 will retain their nuclear and conventional roles, while the B-1B will carry out only conventional missions.

Heavy bomber force planning raises two fundamental concerns: the kinds of capabilities — weapons and avionics — these bombers should have, and how many bombers of each type are needed to meet US military objectives. During 1994, IDA was asked to undertake two major studies to help answer these questions. The first, a cost and operational effectiveness analysis (COEA) for the B-1B's conventional mission upgrade program, examines a range of weapons and defensive avionics systems to determine which alternatives are the most cost effective. Results of our study will support Defense Acquisition Board decisions on development of accurate GPS-aided munitions and an electronic countermeasure system for the B-1B. The second study, directed by Congress, is a comprehensive analysis of the capabilities of alternative mixes of B-1Bs, B-2s, and B-52Hs needed to fight two nearly simultaneous major regional contingencies. This analysis will contribute to DoD decisions on the size and composition of the bomber force.

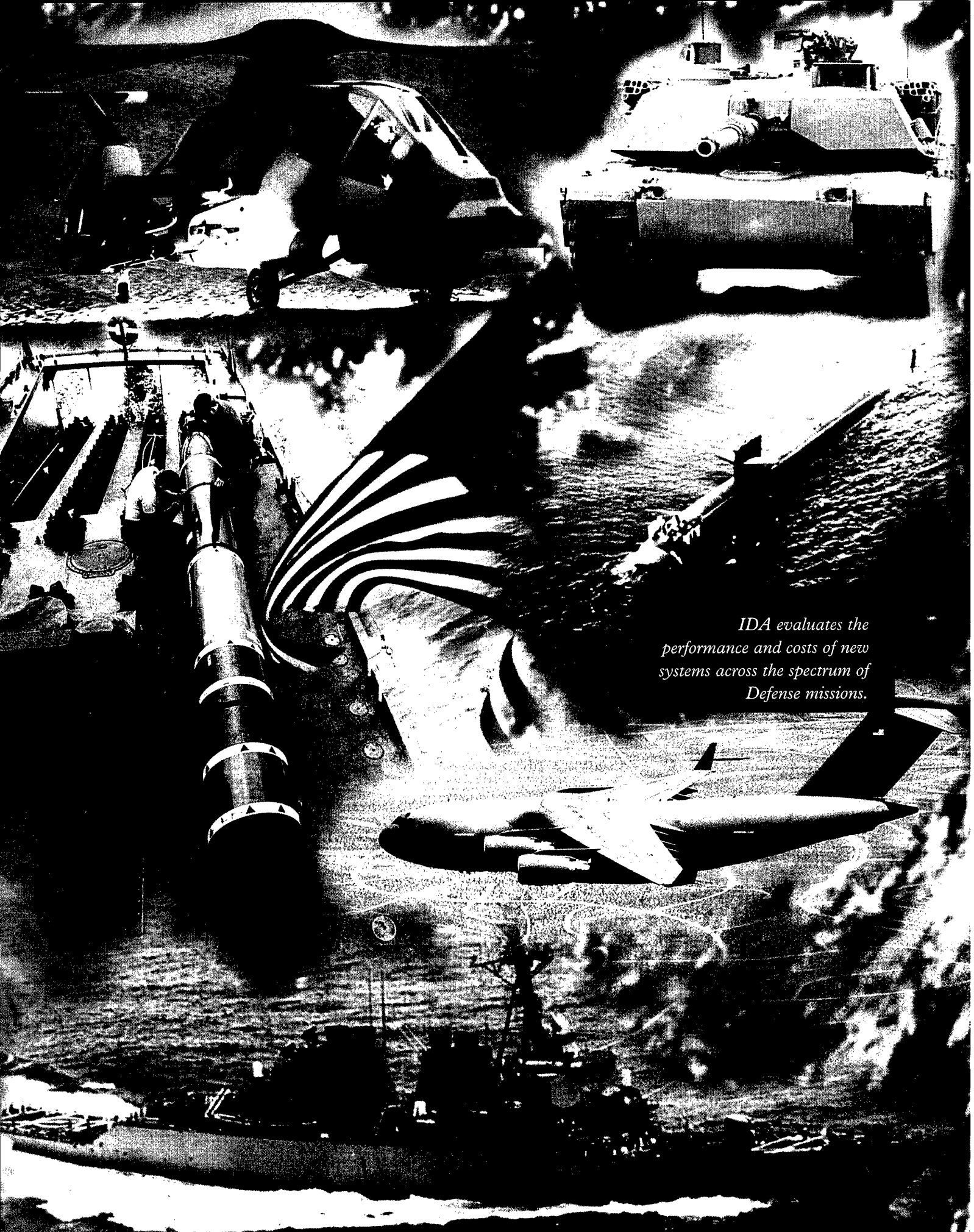
Airborne Tanker

Changes in the size, structure and missions of US air forces have led to arguments for both more and less airborne tanking. The Navy has retired all of its dedicated carrier-based tanker aircraft, intending to rely almost exclusively on land-based KC-10, KC-135, and KC-130 tankers for in-flight refueling. Meanwhile, the Air Force has shifted its emphasis away from refueling strategic bombers to refueling aircraft involved in conventional conflict and humanitarian aid. To further compound planning, tanker aircraft use different, mutually incompatible refueling systems for Air Force and Navy aircraft. With these changes in mind, OSD asked IDA to provide an independent assessment of airborne refueling needs, taking account of the competing forces influencing airborne tanker requirements.

Our study evaluated tanker needs for both strategic missions and regional conflict. We found that some needs are most economically met by modifying existing tankers, rather than by procuring new ones, at least for the near future. One such modification is attaching fuel pods to tankers so as to permit refueling of more than one aircraft at a time. Another modification is installing refueling receptacles on most KC-135s to permit offloading fuel from one airborne KC-135 to another. The results of this study will provide DoD with an analytical foundation for defining total tanker inventories and future modification plans.

Comanche Risk Review

The Comanche armed reconnaissance helicopter is being developed by the Army as a replacement for its existing fleet of light attack and scout helicopters. The design incorporates a number of advanced features, including an all-composite airframe, fly-by-wire flight controls, an integrated avionics suite, and reduced radar,



IDA evaluates the performance and costs of new systems across the spectrum of Defense missions.

infrared, and acoustic signatures. Early in 1994, the Army determined that it would be difficult to complete development of the Comanche within its projected funding levels. As an alternative, the Army proposed a "streamlined" development approach that combined the remaining demonstration and validation development activities with engineering and manufacturing development into a single development phase. To further reduce program costs, the Army sought relief from a variety of Department of Defense and legislative regulatory requirements. With these changes, the Comanche Program Office believed development could be completed with currently planned resources. When the Army's streamlined development plan was presented for OSD review in May 1994, questions were raised concerning program risks.

To answer these questions, OSD asked IDA to establish a panel of outside experts to examine, in conjunction with IDA research staff, the impact of the Army's proposal on program risk. Based on its assessment, the panel agreed that the streamlined approach offered advantages but recommended periodic high-level OSD reviews to ensure appropriate oversight of development efforts. In addition, the panel proposed increasing both the number of prototype helicopters built for flight testing and the number of test hours flown. The panel also recommended the Comanche Program Office seek relief from several regulations and policies that impose a financial burden disproportionate to the likely benefits.

Attack Submarine Force Levels

The number of US attack submarines needed in the post-Cold War world depends on a complex interplay of scenarios and missions, and on the estimated capabilities of submarines versus alternative systems. In 1992-93, DoD conducted a study of this issue based on approved planning scenarios and traditional submarine missions. The Office of the Secretary of Defense asked IDA to provide an independent review of this study to explore whether changing the capabilities of other types of forces might enable them to carry out some missions traditionally assigned to submarines, and whether the results of the DoD's internal study might change if such alternatives were considered.

Our study concluded that the results of the DoD study were driven by the use of submarines in submarine-unique roles. However, we identified a number of other issues which heavily influence force-level recommendations. These include the potential for achieving improved peacetime force efficiency through multiple-crewing or forward home-porting; the potential for reducing the demands on attack submarines for training and surveillance; and an assessment of the contributions of submarines in support of naval task forces.

Near-Term Naval Mine Countermeasures Capability

The severe damage to two US Navy warships caused by Iraqi sea mines during the 1991 Persian Gulf war heightened DoD's concern for the threat that mines pose to naval operations. Because of their relatively low cost, many smaller nations have acquired significant mine inventories. Close to 50 navies have mines and mine-laying capabilities, with roughly 25 nations manufacturing sea mines for export. The ready availability of sea mines, combined with their demonstrated performance, seem likely to make mines a serious threat in future conflicts in littoral areas.

IDA was asked to assess the capabilities of US forces to carry out mine countermeasure (MCM) operations and to identify near-term improvements. Our analysis examined the operational capabilities and limitations of mine countermeasures ships and helicopters, explosive ordnance disposal personnel, and Navy Special Warfare units. We assessed the combined abilities of these forces to conduct minefield reconnaissance, choke-point mine clearance, mine clearance for amphibious operations, and mine warfare command and control. Potential enhancements were identified in four key areas: mine reconnaissance, airborne

MCM capability, MCM in very shallow water (depths of 10 to 40 feet) and the surf zones (depths less than 10 feet), and mine warfare C4I.

THAAD Software Development

The Army's Theater High Altitude Area Defense (THAAD) interceptor system is expected to be a major advance in ballistic missile defense capabilities. However, its demanding hit-to-kill approach with multiple dispersed launchers and firing batteries involves difficult software requirements. The system incorporates multiple communicating processors to coordinate, in real time, the operations of battle management, command, control, and communications (BM/C3) systems, ground-based radars, missile launchers, and missiles in flight.

IDA is helping identify design and implementation issues for flight-test software. These issues include communication and coordination among the onboard missile processors and the multiple computing tasks on each processor; software safety analyses; and the identification of potential error sources. We are providing recommendations as to how to improve performance in each area.

PAC-3 Missile Review

The proliferation of short and intermediate range tactical ballistic missiles (TBMs) has accelerated since the end of the Cold War, as have US plans to develop defenses against them. A cornerstone of our overall ballistic missile defense capability is provided by the Patriot surface-to-air missile system. The PAC-2 variant of Patriot, first used in combat against ballistic missiles during Desert Storm, provides some capability to counter TBMs. As part of the overall effort to improve our capability, the Patriot system continues to be upgraded. In early 1994, the Army selected a new missile technology — hit-to-kill — for the next-generation Patriot missile (PAC-3).

There are significant risks associated with any new technology, and because of concerns associated with hit-to-kill, OSD requested an independent technical review of the Army's decision. A group of national experts led by IDA reviewed all aspects of both the technical risks and potential payoffs of alternative missile technologies. This group concluded that when all factors are taken into consideration, the Army's decision to further develop hit-to-kill technology for the new Patriot missile was appropriate.

Command, Control and Communications

Assessment of Tactical Airborne Radios

The Navy and Air Force are acquiring different radios to provide air-to-air and air-to-ground communications for tactical aircraft. In response to Congressional concerns with this approach, OSD asked IDA to assess the current DoD acquisition strategy as well as three alternative acquisition strategies based on common radio systems for both Services.

Our study evaluated the effectiveness, cost, and risk of each alternative. The assessment concluded that the Navy and Air Force radio systems were designed to satisfy the requirements of specific aircraft at minimum cost, and that there are sufficient numbers of aircraft to achieve economies of scale in life cycle costs for each system. We found that terminating the radio development program of one of the Services would increase overall acquisition costs without adding significant benefits. Additionally, the current strategy already achieves the major objective of joint interoperability in a communications jamming environment, since both Navy and Air Force radios are implementing approved joint standards for anti-jam communications in the Very High Frequency and Ultra High Frequency bands.

Space Systems

Mission Analyses for NASA

All major NASA missions now undergo an external independent readiness review, designed to assess the risk associated in meeting mission objectives. IDA was asked by NASA to

conduct two of these reviews in 1994: the shuttle-based Atmospheric Laboratory for Applications and Science-3 (ATLAS-3) mission; and the National Oceanic and Atmospheric Administration meteorological satellite (NOAA-J) launched on an expendable booster.

The important issues for both missions centered on the age of the components and anomalies that arose on earlier flights using similar or identical hardware. We concentrated our analyses on these issues and highlighted the areas of greatest risk to achieving a successful mission. These reviews resulted in a number of procedural recommendations which NASA is in the process of implementing.

Space Launch Vehicle Planning

The quantity and types of space support required by the US military have undergone significant change since the early 1990s. At the same time, the level of funding for space systems and the launch vehicles has declined. The Department of Defense is now reevaluating its space support requirements and has asked IDA to assist in this process.

We provided DoD with analyses in two specific areas of future space launch vehicle planning: projected satellite sizing in light of recent advances in electronics and other technologies, and the impact that sizing has on the types of launch vehicles required. We also conducted a detailed assessment of the space launch vehicle industrial base to identify essential capabilities and possible vulnerabilities. The study identified critical areas of concern and cost-effective options for addressing them. DoD is using our results in its construction of an acquisition plan for developing an Evolved Expendable Launch Vehicle. Our space launch industrial base assessment also has been used as the basis for the first in a series of DoD reports to Congress on the state of key sectors of the defense industrial infrastructure.

Expendable Launch Vehicle Panel for NASA

The United States' space launch program is at a crossroads. Current US launch vehicles are based on 1960s ICBM technology and are losing commercial competitions to foreign vehicles. The dominant position once held by the US space launch industry in the international market has eroded from a total control of the market in 1980 to less than a 30 percent share in 1993. The loss of commercial business threatens to force government launch prices higher and to eliminate some launch options entirely.

Congress directed NASA to form an independent, external, industry-led panel to identify near-term opportunities for incorporating mature technologies into existing Expendable Launch Vehicles. The objectives were to reduce costs to the government and to make US launch service companies more competitive in the international marketplace. IDA supported this effort for DoD by setting guidelines for contractor data, analyzing options, and producing a report of the findings. Our capability to handle proprietary information from each of the companies, fuse it with sensitive government information, and safeguard the concerns of all parties, allowed us to perform a critical role in the process.

This effort demonstrated the value of evolving the existing fleet of launch vehicles in order to meet government needs in a cost effective way. The panel developed detailed plans for technology infusions for each of the three Expendable Launch Vehicles considered (Atlas, Delta, and Pegasus), which, if implemented, could reduce launch service costs by 25 percent by the year 2000. It also constructed a plan for across-the-board improvements in US launch vehicles. These plans are being used by the Department of Defense in its formulation of an acquisition plan for an Evolved Expendable Launch Vehicle.

TEST AND EVALUATION

IDA continues to provide primary analytical support to the Office of the Director, Operational Test and Evaluation (DOT&E), which is responsible for monitoring operational testing in its various stages. We also provide analytical support for live fire and developmental testing, and for joint test and evaluation.

Operational Test and Evaluation

IDA's technical support for the operational testing of major weapon systems covers three main areas. First, we review and evaluate the adequacy of operational test designs and plans submitted by the Service test agencies. Second, we assist DOT&E in monitoring the conduct of tests, test environments, threat systems, test results, and data collection efforts. Third, we conduct detailed analyses of the operational impact of test results and comment on both the adequacy of testing and the demonstrated effectiveness and suitability of the system being tested. IDA conducts these analyses independent of the Service test agencies and provides significant assistance to DOT&E in the preparation of reports to the Secretary of Defense and to the Congress.

Land Warfare Systems

During the past year, IDA prepared independent operational assessments of the M1A2 tank, the Javelin man-portable anti-armor missile system, and the Kiowa Warrior armed reconnaissance helicopter. The M1A2 and Javelin assessments were major inputs to the reports submitted by DOT&E. This past year also has seen significant advances in the use of computer graphics to plan operational tests, verify the quality of data collected, review trials, and analyze the results observed. Together with the Army, IDA developed the Operational Test Visualization (OT-VIS) software, which has supported testing of the M1A2 tank and the short-range unmanned aerial vehicle. We are developing future OT-VIS applications for operational tests of the Longbow Apache attack helicopter, the Nuclear, Biological and Chemical Reconnaissance System and the Armored Gun System.

Naval Warfare Systems

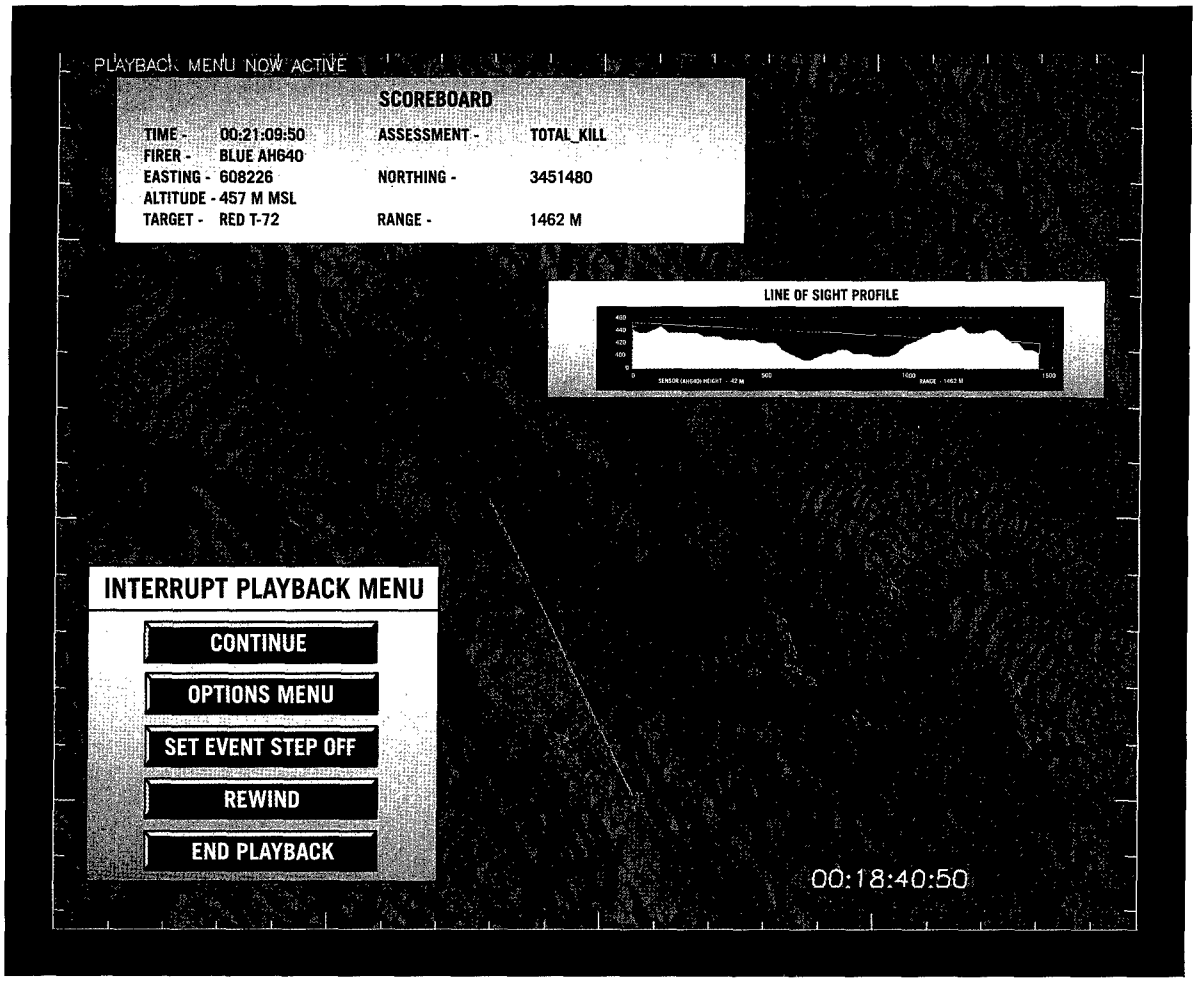
In 1994, our work included the development of test and evaluation concepts for Navy surface, subsurface, and aviation systems, including the New Attack Submarine and the future amphibious ship class, the Landing Platform Dock (LPD) 17. Our concepts emphasized realistic test environments and, in the case of the LPD 17, increased reliance on user-oriented, early operational assessments conducted during ship design.

We also monitored the testing of the Mk 48 Advanced Capability (ADCAP) torpedo and the *USS Arleigh Burke* Guided Missile Destroyer (DDG 51). Our analysis of the Mk 48 ADCAP emphasized its effectiveness in a shallow water environment and assessed launch platform tactics and survivability as a function of threat. IDA's analysis of the first at-sea operational testing of the DDG 51 class ship demonstrated the need for a more realistic command, control, and communications environment for testing.

Air Warfare Systems

IDA supported DOT&E in its assessment of new aircraft, including the T-45, the F-22, and the C-17. We monitored the Navy's operational testing of its new advanced undergraduate jet pilot trainer, the T-45A Goshawk, and related training equipment. Independent analysis of the T-45A supported DOT&E's report on the readiness of the T-45 to enter full-rate production.

Our assessment of test planning for the F-22 program emphasized the need for a comprehensive test plan that would adequately address operational suitability. We also examined the state-of-the-art of Distributed Interactive Simulation and its potential application to some elements of the F-22 Initial Operational Test and Evaluation.



These windows are examples of the information displayed during an OT-VIS playback of a Longbow Apache force-on-force trial. In the main window, icons representing the red and blue forces are displayed over the terrain database. A blue-on-red firing engagement is indicated by the blue line connecting two units. The top window summarizes the position data on the two units and the outcome of the engagement. The next window displays a line-of-sight profile between the two units. The menu at the left shows some of the options available during a playback.

In FY 1994, the C-17 program moved into its third year of flight testing. At year's end, the Developmental Testing phase was nearing completion, and the pace of Operational Testing activities accelerated, including intensive reviews of the operational test and evaluation plans. Having continuously conducted operational effectiveness and suitability analyses using both test data and computer simulations, we are prepared to support DOT&E in the ambitious program of operational testing planned for FY 1995.

Strategic and Space Systems

In 1994, we performed a detailed assessment of the B-1B, which, under current plans, will be for many years the Air Force's primary heavy bomber for conventional missions. Because the B-1B had not achieved its planned readiness rate, Congress directed a six-month test to see if the bomber could meet its readiness objectives for conventional conflicts. Congress further requested that DOT&E monitor the test and review and comment on the results. IDA conducted

independent analyses of the test results to ensure that the test objectives were being met and that testing was conducted in an operationally realistic manner. These analyses will be important inputs to DOT&E's overall assessment of test results.

Command, Control, Communications and Intelligence (C3I) Systems

During 1994, IDA contributed to the design and monitoring of tests for the Army Tactical Command and Control System, which included the Combat Service Support Control System, the All-Source Analysis System, and the Enhanced Position Location and Reporting System. All three components were integrated and tested in the III Corps Phantom Saber command post exercise. Our analyses of data from these tests are expected to support acquisition decisions for these programs during 1995.

IDA examined the Navy's E-2 radar modification, which underwent operational testing to support the upcoming production decision for new Group II aircraft. We also assessed the effects of integrating Air Force Airborne Command Post functions aboard the Navy's E-6A TACAMO aircraft. And we observed the Joint Tactical Information Distribution System's operational performance aboard a carrier battle group in support of full-rate production decision in early 1995.

Electronic Warfare Systems

We continue to assist DOT&E in monitoring operational tests of radar warning receivers and radar jamming equipment. IDA analyses led DoD to establish a requirement for a data instrumentation system to be carried by test aircraft for recording radar warning receiver performance data. We also participated in developing and testing an instrumentation pod and standardized data analysis software to support operational testing of radar warning receivers beginning in 1995.

In our review of Air Force plans for an operational assessment of the self-protection jammer on the F-15E aircraft, IDA analysts recognized an opportunity to increase the understanding of the correlation between hardware-in-the-loop laboratory testing of a jammer and flight testing on an open-air test range. We were able to suggest changes to the laboratory testing that were successfully incorporated into the Air Force test plan.

Major Automated Information Systems

DoD is now reviewing more than 35 Major Automated Information Systems, representing a broad range of computer-based systems for administrative, logistical, and maintenance support to Military Departments and Agencies. In 1994, IDA supported DOT&E in the analysis of operational test materials, test execution, and test results for nine major information systems.

Our independent assessment of the operational testing of the PC-based Composite Health Care System enabled OSD to make informed decisions on its configuration prior to delivery to hundreds of facilities worldwide. Our evaluation of the initial operational testing of the Defense Distribution System helped ensure that a single system could control supply distribution for all the Services before being put into operation at 30 Defense Logistics Agency depots throughout the United States. We also examined the operational testing of a new, large-scale computer system to replace the Army's personnel records system and to provide for direct, electronic update of records.

Another example of the modernization of military information systems is the Unit Level Logistics System for Aviation, which replaces the Army's manual, paper-based procedures for aviation maintenance records. This new system is expected to provide increased awareness of aircraft maintenance deadlines and to streamline the logistics process for repairs. Our analyses identified critical areas for accurately measuring the extent of improvement, and were used after the test to spotlight areas that did not meet performance expectations.

Live Fire Test And Evaluation

Live Fire Test and Evaluation (LFT&E) is used to assess the vulnerability of US weapons systems — with particular attention to minimizing personnel casualties — and the lethality of munitions and missiles. These programs place special emphasis on test realism and the assessment of results in an operational context. Again this year, IDA supported OSD by defining the characteristics of acceptable test and evaluation, by reviewing more than 40 programs, and by preparing independent assessments for three completed test programs: a 120mm tank round, a 25mm cartridge, and the M1A2 Abrams tank.

IDA's support was particularly influential in the M1A2 Abrams tank program. The Army's strategy for the M1A2 LFT&E program had been to use a high-resolution vulnerability model in place of some tests using live munitions on combat-configured vehicles. This would greatly reduce the number of tests, compared with earlier Live Fire Test programs. OSD approved the strategy contingent upon our review of the credibility of the model for this purpose. As a result of our efforts, the Army is redirecting its vulnerability modeling program to improve its usefulness to the test and evaluation community. IDA will be involved in this effort.

Developmental and Joint Test and Evaluation

In 1994, IDA continued to support the Director, Test and Evaluation (DT&E) in the areas of developmental and joint testing. We have analyzed several aspects of the DT&E process, which include developmental test and evaluation capabilities, technical risks, and relationships between developmental testing and technical performance objectives. We also have supported the development of joint test plans and the evaluation of joint test results.

We analyzed the T&E process and recommended to the Director that improvements be made to help ensure that weapon systems are ready for operational testing and/or fielding. After conducting several case studies, we concluded that the Director should, for a limited number of high priority programs, review developmental test plans, monitor selected tests, and conduct his own independent assessment of test results.

We continue to analyze the status of test facilities and resources by assessing trends and relationships in T&E workload, value and age of facilities, and infrastructure funding, and by developing alternative approaches for managing T&E. We also helped the Director evaluate the effects on T&E capability of ongoing and possible base realignments and closures, the Central T&E Improvement Program, and other ongoing T&E projects.

We have been involved in an effort to identify technical risk indicators related to various advanced technologies. In 1993, we identified risk indicators for systems with embedded software, and developed a handbook for applying these indicators. In 1994, we used the handbook to assess an ongoing program, the Joint Surveillance Target Radar System Ground Station Module. We also identified the risk indicators for advanced sensor systems — specifically thermal imaging sensors — associated with both general processes and system-specific processes. These risks and associated indicators are being compiled into another handbook for use by OSD acquisition officials.

In 1994, we provided independent analyses of Joint Air Defense Operations/Joint Engagement Zone (JADO/JEZ) field tests and hosted a JADO/JEZ C3I workshop to identify improvements for joint operations to rectify some of the deficiencies identified during the tests. In addition, we helped assess the contributions of Joint Advanced Distributed Simulations to developmental and operational testing. IDA also provided an independent assessment of the feasibility and potential value of future joint tests of the Joint Combat Search and Rescue System, and the Joint Operational and Intelligence Network.

TECHNOLOGY ASSESSMENTS

IDA conducts a variety of scientific and technical analyses related to national security programs and plans. The range of activities includes basic research, applying new technologies to defense systems, and developing broad technology investment strategies and plans. Areas of particular emphasis in 1994's research program included sensors, observables and space technologies; materials; environmental technologies; and technology planning.

Sensors, Observables, and Space Technologies

Ultra-Wideband Radar

Ultra-wideband (UWB) radar is among the most powerful techniques available for underground and obscured object detection. These radars combine the penetration enhancement associated with high frequencies and the high image resolution afforded by wide absolute bandwidth.

One of the impediments to the use of UWB radars is that they operate in a frequency range used by television and mobile communications services. In 1992, an IDA study demonstrated that, even in remote locations, the resulting radio frequency interference is a limiting factor on system sensitivity. On the basis of this research, the Advanced Research Projects Agency (ARPA) is now examining signal processing techniques that mitigate the effects of such interference on UWB radars. Subsequent IDA research focused on developing new signal processing algorithms which are now in use at several major radar research laboratories. Related IDA efforts are exploring the possibilities for developing a practical surveillance system for sub-foliage target detection.

Synthetic Aperture Radar

Reconnaissance aircraft and spacecraft have begun to rely less on optical cameras for tactical intelligence and more on synthetic aperture radar (SAR), which produces an image of the terrain almost as good as that obtained by optical photography. SAR has two key advantages over optical methods: it can operate day and night, and it can penetrate most cloud layers.

IDA is helping develop advanced SAR concepts and requirements for inexpensive, unmanned aerial vehicles. These aerial platforms will have the capability to hover over enemy territory for extended periods of time and to transmit terrain imagery to a friendly ground station. For SARs with ultra-fine image resolution, the most difficult challenge is the high levels of onboard processing capability and memory needed to process large quantities of imagery. IDA is helping define the technical criteria that advanced processing systems must meet in order to satisfy mission needs.

Infrared Detector Technology

The overwhelming advantage enjoyed by American tank commanders in Operation Desert Storm was in part the result of US superiority in night fighting capabilities. Leadership in infrared sensor technology is critical if this advantage is to endure. During 1994, IDA provided technical support to ARPA related to optoelectronic materials and systems, including assisting in monitoring and assessing the performance of a number of advanced infrared focal plane arrays; identifying critical technical tradeoffs in array specifications; and examining the integration of advanced focal plane arrays in new systems. These efforts have helped define appropriate characteristics for the entire family of new infrared devices now being developed. The Institute also has played a leading role in developing the engineering concepts and design, and for implementing flexible manufacturing procedures for focal plane array production. The result of these efforts has been a more efficient production of high performance infrared sensors.

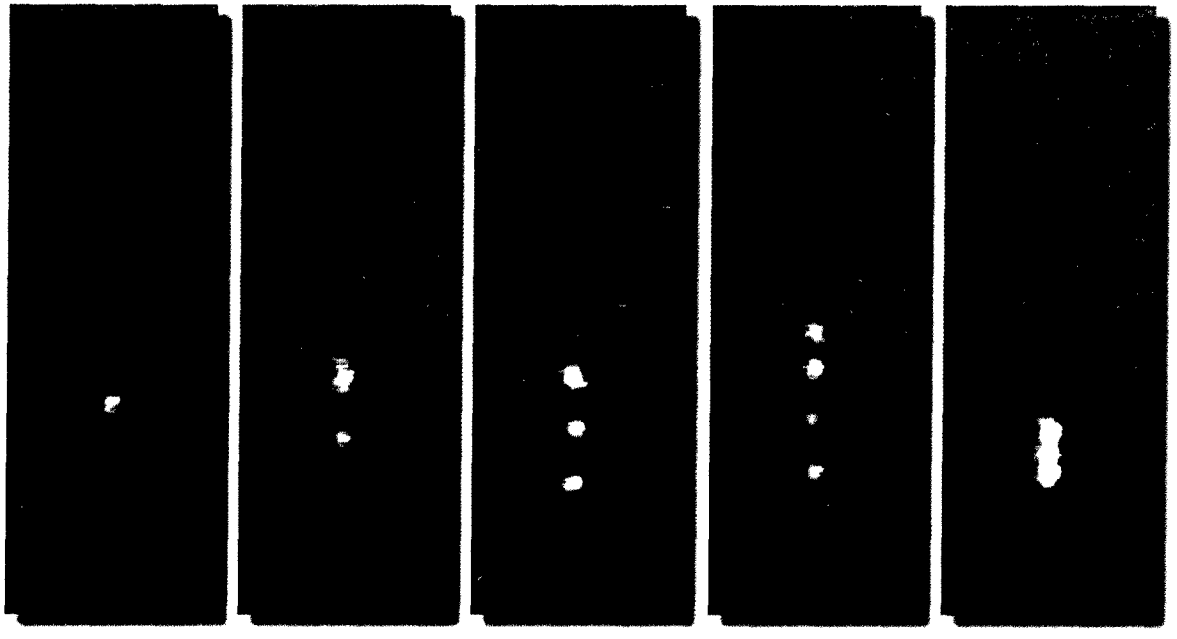
Maritime Mirages

Newly developed ship-borne Infrared Search and Track (IRST) systems, incorporating very sensitive electro-optical devices, can scan the horizon for targets. In tests of these systems, some peculiar optical effects — caused by the atmospheric refraction at these long ranges — have been observed. Single targets produce multiple images that may disappear and reappear within short periods, similar to mirage effects observed by sailors and meteorologists. These multiple images could create havoc for automatic tracking and guidance systems. IDA is investigating the physics of these marine mirages to predict their effect on the operation of IRST systems and to develop techniques for avoiding adverse operational consequences.

Materials

Advanced Composites

The DoD-wide emphasis on affordability in acquisition has extended to programs aimed at developing advanced metal matrix composites for high-performance applications. These traditionally have been very expensive materials with limited reproducibility. IDA's involvement in this area has been along two lines. One effort focused on a joint DoD-, NASA- and industry-supported program to improve the performance of turbine engines through the use of advanced composites — the Integrated High Performance Turbine Engine Initiative. One outcome of our involvement led to the formation of a Fiber Consortium, under which the engine manufacturers, along with the government, cooperatively



Multiple mirage images of a single target
(prepared from data obtained by NSWC/Dahlgren under the HISS program)

fund precompetitive development of ceramic fibers for use in high-temperature composites needed for this program's success.

In a related effort, IDA has been assisting ARPA by conducting technical assessments related to processing and component fabrication technologies for advanced turbine engines. This research has emphasized the use of fiber metal matrix composites and titanium matrix composites in particular. The ultimate goal is to ensure more affordable and higher quality turbine engine components.

Smart Structures

Smart structures are a rapidly growing area of materials research and development, where "smart" implies an ability to respond rapidly to external stimuli in a predictable and compensating way. The Services and Defense Agencies have identified a number of important applications for this technology in areas such as damage detection and control, lifetime prediction, vibration damping, and precision altitude and position control. We are assessing the emerging smart structures technology both for the Ballistic Missile Defense Office and ARPA. This work has led to a number of major new program applications related to monitoring and reporting system health during the conduct of operations, attack warning and damage assessment, and target tracking for submarines, aircraft, missiles, and other military systems.

Ballistic Protection for Personnel

Military personnel carry out peacekeeping, humanitarian relief, and other activities that, while not traditional combat missions, nonetheless expose them to potentially hostile situations. These activities place a premium on minimizing casualties. They also parallel certain domestic law enforcement situations. Recognizing similar intent, ARPA and the Department of Justice are coordinating several research and development activities under the Operations Other Than War (OOTW) program, including ballistic protection for personnel. Both agencies are interested in incorporating newly developed materials into body armor vests for protection against increasingly deadly firearms, while minimizing weight and other vulnerability issues. In addition, the OOTW program will explore novel concepts to address the more challenging area of ballistic protection for body extremities. IDA's initial research in this area, supported by ARPA, is examining the feasibility of applying advanced materials to new concepts for the ballistic protection of personnel.

Environmental Technologies

Cleanup Technologies

Thousands of DoD sites in the United States are believed to be chemically contaminated as a result of many decades of military activity. Common problems at these sites include the presence of organic contaminants such as fuels, solvents and cleaning compounds; industrial wastes such as lead, mercury and other heavy metals; and unexploded ordnance. Dealing with these environmental contaminants and minimizing their impact requires a systematic assessment of the nature and extent of contamination and of the available treatment technologies. DoD has asked IDA to prepare an environmental technology development strategy that addresses both the identification and treatment aspects of this problem.

As a first step, we are developing a composite picture of the contamination at DoD sites. This allows us to evaluate the need for and utility of various cleanup technologies, most of which are typically applicable only to specific contaminants or combinations of contaminants in specific media, such as soil or ground water. We are comparing remediation requirements with existing and proposed technologies to identify those technologies that will reduce the cleanup costs and time. The most highly rated technologies will be priority candidates for DoD investment.

The Institute also has begun a related program of environmental analyses for the Department of Energy's Office of Environmental Management. We are comparing the nature and extent of contamination at DoE sites to that found at DoD sites. The overall purpose is to document the size and scope of the contamination problem for each Department and to identify areas of common concern. The goal is to identify the types of contamination for which one Department should assume a technology lead, and other areas in which technology may be transferred or shared between the Departments. We also are examining the instrumental techniques that are used to perform laboratory tests for different kinds of contaminants. Initial findings indicate that, with the exception of radionuclides, the Departments share similar types of contamination in similar media, and tend to utilize similar techniques for the analysis of contamination.

In 1994, the Congress established an Interagency Environmental Technology Office to identify the shared environmental R&D requirements of the Departments of Defense and Energy and the Environmental Protection Agency, and to select technologies to address shared environmental concerns. This newly created office is tasked with establishing closer working relationships among the Federal Agencies involved in environmental technology development, and reducing the time and cost associated with cleanup through collaborative research activities. IDA has been asked by DoD to identify opportunities for such collaborative work. We are also identifying potential Defense Department environmental technology demonstrations in cleanup, pollution prevention, and conservation.

Pollution Prevention

Preventing pollution at the earliest stages of design is significantly more cost effective than allowing offensive material to enter systems and then attempting to clean it up later. Early identification of intent to use materials, processes or technologies with potentially harmful environmental effects could greatly reduce life cycle costs and mitigate future environmental and programmatic risk. IDA has been asked to identify hazardous or potentially non-compliant materials and technologies now in development, approaching development, or otherwise under consideration for use in Army systems over the next twenty years.

The military forces of many allied nations have operated for decades without adequate consideration of environmental issues. Although a significant effort is under way to deal with the contamination resulting from military operations and training, the sources of the pollution must be stemmed to stop the cycle of recurring contamination. IDA is participating in a NATO Defense Research Group Mid-Term Scientific Study to improve our understanding of the nature of contaminants, hazardous materials and toxic wastes being emitted by ships and from military bases; to identify those technologies and strategies in existence, under development, or planned for future research and development that aim to minimize hazardous emissions, materials and wastes; and to evaluate the applicability of those technologies to NATO environmental pollution prevention concerns.

Finally, DoD acquisition officials and processes must be routinely sensitive to environmental, safety and occupational health considerations in all phases of acquisition: research, development, design, production, and test and evaluation — especially since decisions made in these phases can help mitigate undesirable environmental effects over the lifetime of the system. To this end, we are examining the interlocking oversight and management processes which influence each acquisition phase, such as the Defense Acquisition (5000) Series documents, the Federal Acquisition Regulations, and contract administration policies and procedures. Each of these areas is significantly influenced by the ongoing activities in DoD acquisition reform.

Unexploded Ordnance

Millions of acres of land now or previously owned by the government have extensive subsurface unexploded ordnance (UXO), a side effect of operations conducted at test ranges, training areas, and open burn and detonation areas. Current detection and remediation technology is labor intensive, costly, and of questionable reliability. Since the land is being considered for other uses, finding solutions to this problem has become a national priority.

IDA is providing technical support for a Congressionally mandated UXO Technology Demonstration Program at Jefferson Proving Grounds. The objective of this program is to identify innovative, cost-effective ground- and/or air-based systems for the detection, identification and remediation of contaminated sites. IDA contributions have included evaluations of technical proposals, review of risk assessment models, assessment of phenomenology algorithms, and site selection to ensure more realistic testing of candidate systems.

IDA's research in this area has led to an improved risk model based on historical records as well as performance characteristics of sensors and ordnance. Similar improvements were developed for the algorithms used to correlate UXO target location predicted by the candidate systems with the actual target placement.

In other environmental work, the Institute has provided technical analyses and guidance for the ARPA Super Critical Water Oxidation (SCWO) R&D program. The goal of this program is to develop a portable, reliable, safe system for the disposal of chemical warfare agents. A follow-on program to investigate using SCWO for a Navy shipboard application is under way.

Technology Planning

International Technology Issues

IDA's knowledge and understanding of technology transfer and its implications for national security provides crucial support for the Department of Defense on international technology issues. In December 1993, member nations agreed that the Coordinating Committee for Multilateral Export Control (COCOM) was no longer relevant in the post-Cold War world, and agreed to replace it with a new organization having an expanded membership and its own control lists. COCOM was officially dissolved in March 1994, to be replaced by the "New Forum."

Through the DoD Directorate of Multinational Programs, IDA continues to work with other agencies to develop the technical framework for the formal US Government proposal for items to be placed on the New Forum export control lists. Ultimately, this serves as the basic technical reference for the US Government during negotiations with the other 23 member nations. In addition, IDA researchers also act as technical advisors to DoD representatives during these negotiations.

Cooperative R&D Programs with Russia

The confluence of harsh economic realities, the end of the Cold War, and an openness by many Russian defense R&D facilities all have combined to offer unique opportunities to incorporate some Russian materials and components into future US systems and dual-use products. This situation offers several potential advantages, including the acquisition of novel technologies, reduced research and development costs, and shortened laboratory-to-fielded system time lines.

Taking advantage of these opportunities requires determining which technologies are of the greatest interest, and why. IDA is assisting DoD in developing an integrated strategy and plan of action for exploiting opportunities for cooperative R&D ventures with the Russian defense sector.

Materials Technologies in the Former Soviet Union

For many decades, the Department of Defense has pursued materials research and

development to improve defense systems; the USSR did the same. The end of the Cold War gave birth to exceptional opportunities for access to former Soviet materials technologies.

IDA has been asked by ARPA to examine US Government efforts to survey materials technologies in the Former Soviet Union (FSU), focusing on technologies of interest to US industry. The results of this study are being used by ARPA to develop a comprehensive investment strategy for relevant FSU materials technologies.

Science and Technology Program and Infrastructure Planning

In 1994, the Director, Defense Research and Engineering asked IDA to participate in several important planning activities related to the Department's core science and technology program. One of these efforts — the Defense Science and Technology Strategy — is an overall plan for developing superior technologies that will lead to affordable, decisive military capabilities and enhanced economic security. It establishes five guiding management objectives for the S&T Program: address warfighting needs, reduce costs, strengthen the commercial-military industrial base, promote basic research, and assure quality. This strategy emphasizes the underlying importance of dual use technology and affordability, and establishes three major technology priorities: information science and technology, modeling and simulation, and sensors. In addition, the strategy modifies the building blocks of the S&T Program — basic research, exploratory development, and advanced technology. For example, Advanced Concept Technology Demonstrations, which seek to involve warfighters earlier in the technology development process and speed the transition of technology from the laboratory to the field, are new and important features of the advanced technology program.

IDA worked closely with the DDR&E and the S&T executives of the Services and Defense Agencies to help develop the strategy and the mechanisms through which it would be implemented. Among those mechanisms is the *Defense Technology Plan*, a collection of Technology Area Plans published as an integral part of the *Defense Science and Technology Strategy*. These plans provide each Service and agency with a roadmap to achieve the goals set forth in the strategy for each of 22 technology areas.

The DDR&E also requested IDA's assistance in a study of the roles of the defense laboratories and their relationship to science and technology performers in other government agencies, industry, and academia. The Laboratory Infrastructure Capabilities Study, as this effort came to be known, brought together panels of experts from within and outside the government in each of the 22 technology areas identified in the *Defense Technology Plan*. IDA organized the non-government panels, drawing on more than 500 experts nominated by professional and trade organizations.

The report — written by IDA in concert with panel members — identified and discussed the important functions served by the laboratories and generally agreed that as DoD's budget shrinks, the Department needs to define the critical mass of capabilities that must be performed within the government. The report also offered a broad range of proposals for restructuring the defense laboratory system, and articulated a number of long-standing concerns about regulations governing laboratory work forces and procurement. This study provided the basis for the DDR&E's report to the National Science and Technology Council as part of its government-wide review of laboratories.

INFORMATION SYSTEMS AND TECHNOLOGIES

Constantly expanding computing capabilities and advanced information system technologies provide DoD with new opportunities for more effective utilization of its information resources. IDA helps DoD meet these information challenges through technology analyses, technology standards development, and some systems prototyping.

IDA has a long history of assisting DoD in addressing its requirements for employing best practices in the engineering of information systems. Recent IDA activities in this area include work on object-oriented software engineering, evaluation of current real-time design methodologies, and development of a plan to improve "software metrics."

Object-Oriented Technology

In an effort to reduce software costs, the Defense Information System Agency is introducing object-oriented technology to its information systems development activities. These systems support such functions as personnel, logistics, medical services, and accounting. Most existing systems are characterized by outdated technologies and heavy maintenance demands. Object-oriented technology, which structures software specifications and code around real-world objects, provides a more intuitive basis for building systems. The use of object-oriented technology often leads to more maintainable and reusable software systems, which can result in substantial cost savings.

IDA provides primary analytic support for DISA's Object-Oriented Technology Program. We have developed strategies for exploring issues related to the use of object-oriented technology in today's information system environment, strategies that provide specific technical guidance when reengineering old systems or conducting a new systems development. To address organizational challenges, we developed a technology transition guidebook for moving object-oriented technology into a DoD software development organization. The book provides step-by-step guidance for managers and developers on planning, training and mentoring, conducting pilot projects, and full-scale organization transition. We also are conducting a pilot project with Marine Corps Manpower and Reserve Affairs to reengineer their Officer Assignment System. This pilot project tests a variety of object-oriented analysis and design techniques, languages, and development tools.

Software Metrics Analysis

The term "software metrics" refers to data about computer software development projects. Metrics include product attributes such as reported defects and lines of code, as well as project progress factors such as expended funds and effort. A recent IDA study compared DoD and industry software metrics practices and recommended a DoD improvement plan to benefit weapon system acquisition.

We found industry practice to be generally more mature and further evolved than that of DoD organizations. Within industry, defense contractors and strictly commercial organizations have comparable maturity. Companies are pursuing long-term marketplace benefits from metrics, and thus are establishing company-wide metrics policies and measurement support groups and investing in better metrics tools.

DoD organizations focus on helping individual acquisition program managers, but this support is limited. For example, specific metrics are recommended without sufficient guidance for incorporating them into practical program management.

IDA proposed a plan for DoD metrics improvement with the overall vision of establishing a department-wide, bottom-up approach for collecting and using software

metrics. A key element of this plan included leveraging from industry's metrics practices rather than creating standard DoD metrics which would impose an added burden for contractors. Another element was the establishment of a system for transmitting summary metrics and trend data to the Services and OSD. Such data would be used to improve acquisition and risk management practices department-wide, not to monitor individual programs.

Database Design Educational Tool

To improve software engineering education, DISA and OSD asked IDA to develop a software teaching tool that could be used in computer science courses to augment textbooks with laboratory demonstrations of theory. In September, we delivered the first version of this teaching tool to the DoD software repository and to computer science colleagues at New York University. We also made it accessible on the Internet.

This tool is a relational database management system designed to demonstrate software engineering principles of modularity, portability, and maintainability. Implemented in the Ada programming language, the software can be reused and enhanced by students or their instructors. The software tool and a companion teaching guide will help improve software engineering and database courses.

Computing Standards

With the growing emphasis within DoD on integrated and interoperable information systems, the importance of standards for information technology is gaining greater visibility. For several years we have been developing, maintaining and expanding a detailed survey of information technology standards. This document is used by information systems planners and architects to learn about the current state and future direction of standards efforts, and by DoD standards personnel in developing guidance for current programs.

In the increasingly important area of multimedia technology, we are identifying DoD needs, monitoring the efforts of industry and standards bodies as they grapple with complex standardization issues, and evaluating technical areas where standards may be required by DoD programs. This work is aimed at helping DoD understand this complex area in order to provide guidance to multimedia users.

Computer security is another area of standards activity at IDA. We have led the development of the next generation computer security evaluation criteria for trusted distributed systems; this work will become a key part of the emerging international standard for information technology security. We also investigated the use of security labels across all elements of an information system and provided recommendations on potential areas of standardization.

Defense Information Infrastructure

The Defense Information Infrastructure (DII) is the DoD-wide system of computing and communications assets configured to satisfy the information requirements of the Department of Defense as a whole. It connects multiple information systems, encompasses the diversity of all DoD missions, and extends through every DoD entity and into the outside world.

The DII is intended to increase DoD capabilities in many arenas. For example, the DII could potentially improve warfighting capability by providing an affordable information system for the soldier and those units that support him or her. For a modern defense system, this requires interoperability between command and control, intelligence, and mission support

systems. It also must make data stored any place within DoD systems available to authorized users on demand. Eventually, this may include access to data held by other US government organizations, allies, and coalition and industrial partners.

Historically, organizations within DoD have developed and acquired information to perform their mission separately and independently. In this manner, the success of the mission was totally controlled by that organization. The experiences in Desert Shield/Storm demonstrated the importance of interoperability across the functions and the Military Departments, as well as the hierarchy within each Service. As a result of these real world experiences, there is now a broadly based commitment within DoD to transform existing information systems into a seamlessly interconnected, survivable, resilient, secure, and evolutionary information infrastructure — the DII.

IDA has been working with DISA to establish the attributes of the DII. The problems are not only technological but also involve cultural, sociological, and political issues. We are helping to clarify the problems and to suggest mechanisms to solve them.

One example of IDA's support for the DII is our analysis of the emerging DoD Goal Security Architecture (DGSA). IDA played a key role in the development of the overall transition strategy intended to facilitate the evolution from legacy systems to systems compliant with the new security architecture. IDA also assisted in the development of specific DGSA transition plans in the key areas of research and technology, products, and standards.

ADVANCED SIMULATION

The Institute for Defense Analyses is a leader in the application of advanced simulation to the readiness and training of our forces and to support the acquisition of affordable, technologically superior weapons. Advanced Distributed Simulation (ADS), based on high-capacity network, display and computing technologies, provides a virtual environment in which weapon systems, soldiers, and commanders can exercise and communicate as though they were on a common battlefield. This enables more frequent training opportunities at less cost, and allows early examination of new weapons concepts.

Advanced Distributed Simulation has applicability to areas such as telemedicine, virtual manufacturing, and distributed enterprises. There are significant challenges both in developing the underlying technologies, and in learning how to use ADS most effectively in new areas.

Recent IDA contributions in this area range from basic assessments of the technologies to concept demonstrations and analyses. They relate to issues particularly important to DoD as well as those with broader application.

Simulation Technology Evaluation

Simulation Architecture

The Department of Defense recognizes the need for an architecture that will facilitate the interoperation of simulations of various types, including virtual simulations, constructive wargames, and live ranges. IDA has been active in the development and promulgation of this architecture, working with the Defense Modeling and Simulation Office (DMSO), the Advanced Research Projects Agency, and the Joint Simulation System Joint Program Office. As part of this effort, IDA has served as co-chair of the DMSO Technical Working Group on Simulation Architecture. We also drafted the architecture sections of the DoD Modeling and Simulation Master Plan and provided independent technical assessments of a broad range of architecture issues. Furthermore, IDA was a major participant in the ARPA-initiated Program Evaluation Team assembled to provide the first version of a high-level architecture for advanced distributed simulation.

Developing and Demonstrating Technologies for Advanced Distributed Simulation

The IDA Simulation Center provides a unique laboratory environment for early assessment of new ADS technologies. During 1994, we helped evaluate new developments in several basic research areas. For example, IDA served as a test site for the DSI Phase I Enhancement Program and Simulation Scaleability Algorithm research. In the area of synthetic environments, the Institute was the primary site for comparisons of new display systems. Soon to be tested are new technologies emphasizing the individual combatant, including synthetic environments for urban areas, and I-PORT, a device that allows the soldier to participate in the virtual world.

Application of Advanced Information Technologies to Simulation

IDA reviewed a number of advanced information technologies under development at ARPA to identify those most relevant to Advanced Distributed Simulation. Key among these are domain modeling, software prototyping, intelligent integration of information, distributed collaborative planning, and human computer interface technologies. We conducted a workshop and a series of experiments to further explore identified technologies.

An Architecture Technologies Workshop at IDA convened representatives from the simulation community, including the Synthetic Theater of War (STOW) program, WARSIM 2000, and the JSIMS (Joint Simulation) program. The workshop included briefings and demonstrations in the area of Architecture Description Languages, Architecture Driven Environments, and Component Interoperability and Evaluation Tools. The results of the workshop will contribute to the development of a DoD-wide architecture for modeling and simulation.

In the area of Distributed Collaborative Planning, IDA conducted numerous demonstrations in support of TRANSCOM,

IDA's Simulation Center continues to be a focal point for DoD activities related to developing and using advanced distributed simulation technologies. Over the past year, these activities have included investigating new and upgraded simulators; participating in large simulation exercises such as the Synthetic Theater of War - Europe demonstration; setting-up a "bunker" to explore the value of synthetic environments; hosting an interagency conference -- chaired by then Deputy Secretary of Defense John Deutch -- on the use of DoD technologies to enhance nation-wide learning; and conducting wargames utilizing a new Bosnian

PACOM and the Louisiana Maneuvers Task Force. We also conducted a variety of experiments on the Multicast Backbone, which serves as a testbed for audio and video Internet experimentation.

Training and Analytic Applications

The Synthetic Theater of War Program

The ARPA Synthetic Theater of War (STOW) Program is an Advanced Concept Technology Demonstration that will explore the utility of distributed interactive simulation for joint task force training. USACOM plans to begin using this new training capability in 1997. IDA assisted ARPA in the concept definition of STOW and will provide ongoing independent technical evaluation of the system as it is constructed and used.

Begun in 1992, STOW is setting the pace for technology development in real-time networks, synthetic forces and environments, exercise management, and methods and architectures for linking virtual, constructive simulations with live ranges. A key element of the program was the USAREUR STOW-Europe experiment, conducted during the Atlantic Resolve exercise in November of 1994.

The STOW-Europe experiment combined over 2000 entities from live, constructive, and virtual simulations and tested them using an operationally relevant scenario and a defined training objective. It was the most technically challenging experiment of ADS to date, and represented the first time simulations of these various types were combined in this fashion. It also represented a test of ARPA's new approach to developing and transitioning technologies, which is to embody new technologies in existing, operationally useful systems.

Simulators for Prototype Systems

IDA is exploring the use of distributed interactive simulation for systems evaluation of new weapons concepts. Two case studies illustrate how workstation simulators can be used for this purpose.

The Smart Mine Simulator (SMS), developed by IDA researchers, has served as an important analytic tool in several studies. It simulates antiarmor mines and two types of antihelicopter mines, modeling the sensor, the target engagement sequence, and operator command and control capabilities. We continue to enhance this system, and are now in the process of incorporating a variety of conventional mines and countermine capabilities into the simulation.

We also have developed a workstation air defense gun simulator, which models the radar and gun components of air defense systems. To use it, the operator "attaches" the gun to a vehicle on the battlefield. The ease of adding new capabilities to existing vehicles makes this simulator particularly useful.

Cruise Missile Defense

IDA is supporting DoD's use of simulation in the Cruise Missile Defense Advanced Concept Technology Demonstration. This program seeks to exploit advanced sensor designs developed by ARPA and the Services to create a major advance in cruise missile defense. Using advanced simulation, the program will provide the battlefield context in which the warfighting community can evaluate these technologies and refine their use.

The program will include constructive simulations, interactive simulations, user-in-the-loop simulations, and live exercises, with technology insertions for demonstration of the most mature concepts. Through our Simulation Center and its link to the Defense Simulation Internet, we will assist in the design, execution, and evaluation of the simulation experiments.

Improving National Guard Training

During 1994, IDA continued development of the Distributed Janus battle staff training system for the National Guard under the sponsorship of the Advanced Research Projects Agency. This project is part of ARPA's SIMITAR (SIMulation In Training for Advanced Readiness) initiative, which aims to bring advanced technology to National Guard training.

There are major obstacles to National Guard readiness, including the limited number of training opportunities for personnel and the dispersal of National Guard units among geographically distant armories. Distributed Janus helps address these problems by linking brigade headquarters with its subordinate battalions over ordinary phone lines and then providing coordinated simulated combat in the context of an on-demand command post exercise, stressing staff synchronization.

Distributed Janus is derived from the Army's Janus(A) training combat model. IDA has added enhancements to create a wide area network over phone lines linking and coordinating the simulations at each armory and to increase the number of combat service support activities. The latter enhancement increases the participation of the forward support and engineering battalions, which are sometimes ignored during brigade command post exercises.

New Defense Initiatives

Learning Productivity

Over the past half century, the Defense Department has invested considerable funding, energy, and time to improve the skills and readiness of its work force. This investment has involved substantial research and successful development of instructional processes that can be used by learners of widely different backgrounds and abilities. Instructional technology including simulation, networked simulation, interactive multimedia, and video teletraining has been the cornerstone of these efforts.

Returns from this investment have produced significant benefits for civilian as well as Defense education and training activities. Because of these benefits and their promise for increasing learning productivity, the Deputy Secretary of Defense asked IDA to organize a seminar to share the results of DoD investment in simulation and other instructional technologies with other parts of the federal government, such as the National Economic Council, the Office of Science and Technology Policy, the Domestic Policy Council, and the Departments of Commerce, Education, and Labor. Following this seminar, IDA assisted its participants in establishing cross-agency initiatives to exchange technical information on simulation, networked simulation, and other instructional technologies; a private sector coordinating council for education and training; a cross-agency strategic plan for R&D in education, training, and life-long learning; and an interagency office for coordinating and leveraging the education and training activities of federal agencies.

IDA continues to assist various federal agencies and other organizations in developing procedures, initiatives, and programs that capitalize on DoD's investment in advanced simulation and other instructional technologies that enhance the productivity of learning.

Simulation-Based Design

The ARPA Simulation-Based Design (SBD) Program is developing processes to reduce significantly the costs and time involved in determining system requirements, concept design, engineering design/development, and production. The program seeks to integrate a variety of technologies for these purposes, including computer-aided design, manufacturing and engineering, operational analyses, modeling and simulations, and life cycle costing.

IDA was asked to survey companies and universities within the United States, Japan, and Europe to ensure the latest integration methods were included in the program and that ARPA's planned efforts would represent a significant advancement in the field. Our survey covered more than 81 companies, 43 universities, and 67 government organizations. We concluded that the planned SBD Program would bring significant value added to integration technology, for several reasons. The program defines the framework/architecture for effective and efficient integration of large systems; it determines and develops appropriate initial and follow-on tools; and it demonstrates its advances on a real system(s) and shares the results with a large number of "involved" DoD and industry organizations.

STRATEGY AND FORCE ASSESSMENTS

The Institute performs a variety of interdisciplinary studies of issues concerning national security strategy, the structure and capabilities of US forces, and defense infrastructure and logistics. During the past year, our efforts in these areas have included assessments of weapons proliferation and control problems, contingency force planning, and new challenges as we approach the 21st century.

Weapons Proliferation and Control

The post-Cold War world is well understood to present both new dangers and new opportunities. This is especially evident in advanced weapons technology, particularly that associated with weapons of mass destruction (WMD). Vigorous economic competition between Western, East European, and former Soviet nations has made sophisticated weapons systems increasingly available. While trade in WMD and associated production equipment is broadly prohibited by international agreement or norm, nations such as North Korea are proving more and more successful in their attempts to develop indigenously these dangerous weapons. With the absence of a superpower enemy, regional aggressors armed with the best conventional weaponry — and in some cases with WMD — have become an increased threat to US interests and forces. Efforts to deter and control these threats remain a central focus of military planners and policy makers.

Yet the end of superpower competition also has ushered in an era of cooperation among former adversaries in controlling or reducing common threats. Entry into force of the START treaty, establishment of the Organization for the Prohibition of Chemical Weapons, and expansion of the Missile Technology Control Regime are among the more prominent examples of cooperative initiatives undertaken in 1994. Exploration of new opportunities for cooperation can build on these successes.

Scope and Content of an Acquisition Program to Counter Proliferation

DoD's long-range modernization plans will be influenced by efforts to counter the effects of continued proliferation of nuclear, biological, and chemical (NBC) weapons. We examined the implications of nine categories of potential counter-proliferation efforts, ranging from obvious actions, such as developing capabilities to find and destroy opposing NBC capabilities before they can be used, to less obvious actions, such as preparing potential coalition allies to share the risks and burdens of confronting NBC-armed regional challengers.

Some challenges identified are: 1) an effective answer to NBC proliferation requires far more than technological responses; 2) major efforts will have to be made to prepare potential coalition partners for their roles in implementing collective actions to deter NBC-armed regional challengers; and 3) maintaining an allied intervention capability — one which an opponent cannot stop with modest numbers of nuclear strikes against logistics and infrastructure targets — will be an expensive undertaking.

Constraints on Antipersonnel Landmines in Future Conflict

Antipersonnel landmines are sometimes referred to as "weapons of mass destruction in slow motion." The State Department has estimated that 85-90 million unexploded landmines are currently scattered across some 62 countries worldwide. These mines kill or maim between 600 and 1200 people a month — most of them civilians, many of them children — and remove countless acres of arable land from active cultivation. IDA is exploring options for addressing this humanitarian crisis through negotiated controls on the manufacture, stockpiling, sale or use of antipersonnel mines.

The initial phase of our work addressed the military utility of landmines. Our central

conclusion is that the potential military benefits of landmines — and especially antipersonnel mines — in high intensity conflicts are not so great as to rule out future arms control discussions. This is not to say that any particular proposal is in the US national interest. To determine that would require a broader assessment of the issues associated with landmine arms control, such as verification provisions, costs and humanitarian benefits, as well as military utility.

Rocket Demilitarization in Ukraine

American negotiators are working with the government of Ukraine to develop a demilitarization assistance program under the auspices of Cooperative Threat Reduction, a Congressionally mandated program of assistance to the four Republics of the former Soviet Union that inherited nuclear weapons during the breakup. This year, IDA assisted OSD in supporting the negotiators by evaluating demilitarization proposals for Ukrainian SS-19 and SS-24 strategic missiles slated for destruction.

Dismantling the liquid-fueled SS-19s will yield 6000-10000 metric tons of nitrous oxide and 3000-5000 metric tons of unsymmetrical dimethyl hydrazine. We examined a number of alternative disposal methods, including use as a synthesis ingredient in a class of chemicals known as aminimides, conversion to dimethylamine, use as a fuel, and incineration. With the notable exception of incineration, we found significant uncertainties in the costs and benefits of these approaches.

For disposal of Ukraine's SS-24 missiles, IDA examined solid-fuel disposal procedures used in the past and under development in the United States. Past procedures are well established, unambiguous, and inexpensive, although legitimate questions exist about their environmental impact. Newer procedures that could prove more acceptable include machine removal, washout by various fluids, enclosed burning, and supercritical water oxidation. Our review suggests that machine removal of propellants, which could then be used as explosives in civilian applications, appears to be the most promising alternative to existing methods.

The Changing Face of Conventional Arms Control

Conventional arms control, defined broadly to include such areas as confidence building and transparency measures, peacekeeping, and restructuring of European security institutions, has been changing since the end of the Cold War. Regional opportunities for arms control have increased. At the same time, more supporting technologies are becoming available.

IDA has continued to examine the ways in which conventional arms control has changed, and what opportunities are thus presented to the United States. We concluded that there are many potentially useful regional arms control initiatives, particularly confidence building measures that could decrease the likelihood of misunderstanding legitimate and strictly defensive changes in states' military postures. We also found that regional arms control measures aimed at enhancing stability will be more difficult to pursue, influence, and underwrite than will more traditional arms control involving US forces directly.

Contingency Force Planning

Defense planning has become more difficult in the new world. Because today's threat environment is rapidly changing, planning based on specific politico-military scenarios is harder, particularly for the long term. At the same time, budget constraints will slow future modernization rates, so that near-term program decisions will have longer term implications. Understanding the consequences of planning decisions made

today is thus increasingly important. As part of our studies of contingency force planning, we are involved in two prominent evaluations of joint Service operations: the conduct of Joint Warfighting Capability Assessments with DoD, and a reexamination of Service responsibilities by the Congressionally mandated Commission on Roles and Missions of the Armed Forces.

Joint Warfighting Capability Assessments

In recent years, the Chairman of the Joint Chiefs of Staff has been assigned broader responsibilities by public law and Defense directives. To facilitate execution of these responsibilities, the Joint Staff has established a new process in which Joint Warfighting Capability Assessments are conducted in nine mission areas. During 1994, we provided analytical assistance to two of these — Air Superiority and Strike Warfighting Assessments. Our support to the Assessment Teams falls into two categories: analyses of certain broad issues such as "combat aircraft recapitalization" — deriving the budgetary implications of modernizing combat aircraft; and extracting, compiling, and organizing relevant data from existing studies, analyses and reports of exercises and combat operations. The latter provides an end-to-end perspective of planned forces' capabilities to conduct the component tasks of their missions. The Joint Staff Assessment Teams will use these data to evaluate how well the plans and programs conform with Defense Guidance and CINC's priorities. Where the Teams' assessments identify specific problems, IDA will conduct analyses of options to address them.

Commission on Roles and Missions of the Armed Forces

The current allocation of roles, missions, and functions to the Armed Forces evolved after World War II to meet the demands of the Cold War. Many in Congress anticipate that greater efficiency and effectiveness could result from a realignment of responsibilities in the new environment. Lower future budget prospects also argue for a new examination of these responsibilities. The FY94 Defense Authorization Act therefore instructed the Secretary of Defense to establish an independent Commission on Roles and Missions of the Armed Forces to review current responsibilities, evaluate alternatives, and recommend change.

IDA has supported the Commission's deliberations almost from the start. During 1994, we developed and commented on more than 60 roles and missions issues, from which the Commission members selected those deemed most important for further consideration. These ranged across the spectrum of warfighting missions, organizational infrastructures, and Defense Department processes. The Commission investigated alternatives to the way in which support for these missions is provided, usually by combining forces from more than one military Service, by consolidating control within one Service, or by establishing extra-Service organizations with oversight over similar programs within more than one Service.

For each of about 25 issues, IDA provided cost estimates for the identified alternatives, including near-term transition costs as well as long-term costs or savings. For most issues, we also provided organizational and operational assessments of alternatives. The Commission report was released in May 1995.

A Comprehensive Biological Defense Program

As a result of the Desert Storm experience, DoD identified shortfalls and deficiencies in the US biological detection capabilities. To overcome these deficiencies, the Services established various programs for fielding new bio-detection equipments.

The need for a deeper understanding of biological weapons and for better US biological defensive capabilities — to include the medical aspects of bio-defense — has since been heightened by the growing availability of advanced delivery systems of all types, to the Third World and elsewhere, and the rapid development of biotechnology.

IDA is providing analytical and technical support in the coordination and evaluation of components of DoD's Bio-Defense Plan. The first phase of our effort involves a series of technical and operational evaluations of biological detectors to be developed by the Army. This work also includes an assessment of the tradeoffs between operational, technical, medical and risk factors associated with fielding these new systems. We also are conducting sensitivity analyses of various parameters associated with both the detectors themselves and the scenarios in which they might be used, including the impact of doctrine, training, tactics and organization.

To conduct our analyses, we constructed a series of models and simulations to evaluate the impact of biological defense systems under a range of conditions. The areas covered by these models include strategies for the employment of biological weapons; the downwind dispersion and diffusion of agent clouds after weapon release; the impact of various biological agents on deployed personnel, with and without medical intervention; and the resulting deployment and military effectiveness of biological detectors.

New Challenges in the Post-Cold War Era

The 90s threat environment places a premium on flexible military forces that can perform a variety of missions in a variety of circumstances. This need for flexibility is further bolstered by an increasing use of military forces for humanitarian purposes, ranging from peacekeeping to disaster and famine relief, and for police actions, such as embargo enforcement and drug interdiction. An understanding of the range of new challenges and a determination of their requirements is critical if future forces are to be structured to meet these challenges.

Advanced Sensor and Information Processing Technologies for Peacekeeping Operations

US military forces have been used increasingly for peacekeeping and related regional stabilization operations — from northern Iraq to Somalia, Macedonia and Haiti. It would be desirable to hold down the costs of these operations to prevent them from becoming an ever larger share of future defense budgets. Moreover, the risks to troops participating in these operations must be minimized.

IDA has been examining the use of modern, off-the-shelf sensor and information processing systems to enhance the effectiveness and reduce the risks and costs associated with a number of key peacekeeping missions. While our efforts focused on creating and enforcing safe areas and barriers, we also explored the application of these technologies in four additional peacekeeping missions: monitoring demobilization, monitoring frontier zones, monitoring ceasefires, and enforcing sanctions. Our work suggests that there is substantial promise in applying modern sensors to a variety of peacekeeping missions.

Based on the analysis of 51 multilateral peace operations conducted in the post-World War II period, we identified a set of political and operational constraints affecting the use of advanced sensor systems in peace operations. With these constraints in mind, we identified types of sensor technologies and developed general operational concepts (schemes for responding to sensor data) that would meet the twin goals of improved effectiveness and cost/risk reduction in peacekeeping missions.

CINC Support Activities

Since the dissolution of the Soviet Union and Warsaw Pact, there have been many significant changes in the political and military structures of nations that were members of these organizations. The NATO Alliance also has implemented a number of important doctrinal and organizational modifications in response to these changes and has extended membership in its Partnership for Peace program to its former adversaries. IDA support has assisted the US European Command in meeting these new challenges. Our work in this area has included analyses of emerging doctrine and plans, preparation of documentation, and participation in three series of exercises, all in the form of seminars, conducted by the Command with allied nations and other organizations located in its area of responsibility.

The first exercise series, Joint Movement Control Exercises, focused on topics related to joint and combined deployment and reception of NATO forces during out-of-sector operations. The second series, International Logistics Seminars, was initiated under the Military-to-Military cooperation program with former Soviet and other Eastern European nations. Their objective was to support integration of the military capabilities of Albania, Estonia, Latvia, and Lithuania into each nation's structure for responding to domestic, natural or man-made disasters. The third exercise series, beginning in June 1995, builds on the previous two series and is intended to train the staffs of the European Command and its components in planning and executing a humanitarian relief operation in conjunction with the international community, allied military and civil organizations, other US government agencies, and selected Partnership for Peace nations.

IDA staff have prepared documents for use prior to, during, and after each exercise. These documents have ranged from planning guides and tactical situation summaries to after-action reports. Many were published both in English and in the native languages of the East European participants to facilitate the exchange of ideas and to serve as a resource as participating countries work to improve their own capabilities.

RESOURCE AND SUPPORT ANALYSES

IDA's studies of resource and support issues are designed to measure and estimate costs, and identify opportunities for savings. Declining budgets make it essential that DoD resources are spent efficiently. This is particularly true for procurement funds, which have declined steadily in recent years. The costs of new weapon systems must be estimated precisely to avoid overrunning procurement budgets. In addition, the reductions in procurement imply that infrastructure, support, and software together comprise a larger share of the DoD budget. Those areas offer potential for savings, although care must be taken to understand fully those actions that could reduce readiness or functionality.

System Cost and Schedule Estimation

Analysis of Cost and Schedule Growth

The defense acquisition community has long been concerned that programs to develop major systems take too long and cost too much. Cost overruns force DoD to revise budget and deployment plans, and frequently erode Congressional support for systems under development. In response to this problem, DoD asked IDA to describe schedule and cost growth patterns and to identify underlying causes for cost growth.

We first looked for areas where schedule and cost growth had generally been either widespread or absent. We discovered that tactical missiles have been particularly prone to schedule and cost difficulties, while tactical aircraft have had fewer problems. By comparing outcomes within and between these two groups, we were able to identify factors that distinguish programs completed on time and on budget from those that suffer schedule and cost growth.

Two major keys to preventing schedule growth are technical realism and a willingness to make tradeoffs. Using a strictly phased approach — resolving problems early in the development phase, rather than allowing them to persist into the production — will help prevent schedule growth from causing subsequent cost growth. Other keys to preventing overall cost growth include estimating more accurately the degree of technical difficulty and maintaining the planned production schedule.

Spacecraft Cost Estimating

In the current budget-constrained environment, space systems must become more affordable and must take less time to develop and field. Traditional spacecraft cost estimating is based primarily on spacecraft weight. However, given that the next generation of spacecraft will be lighter and have higher performance characteristics than do current versions, the weight-based approach is no longer adequate.

IDA has constructed an improved model for estimating spacecraft development and production costs. In addition to weight, our model includes such parameters as power, structural materials content, design life, subsystem performance characteristics, prototyping, and system mission. The model also can estimate spacecraft costs under different acquisition environments. We tested our model by comparing actual to predicted costs for the experimental spacecraft Clementine, and found that it predicted costs with considerably greater accuracy than did traditional weight-based models. We have subsequently used this same model to estimate the costs of several proposed satellites for ballistic missile defense.

Schedule Assessment Tools

To ensure that its acquisition programs are completed on time, the Ballistic Missile Defense Organization (BMDO) asked IDA to develop methods for assessing the reasonableness of its proposed acquisition schedules. We collected historical schedule

and program data on several unmanned spacecraft and interceptors, and then performed statistical analysis on schedule intervals. This allowed us to develop time-estimating relationships (TERs), which in turn will enable a program office to predict the elapsed time between adjacent program milestones. We then integrated the individual TERs into a schedule-assessment tool spanning the period from the start of prototyping efforts in Engineering and Manufacturing Development through early production.

We applied our schedule assessment tool to a number of proposed BMDO programs, including spacecraft and surface-based interceptors. We found the proposed schedules for two of the programs to be optimistic. This analysis pointed to the need for BMDO to manage closely the schedule risks for these programs.

Defense Contractor Indirect Costs

The Department of Defense has been attempting to improve its understanding of the indirect costs incurred by its contractors. Because indirect costs now comprise over half of the total cost of defense contracts, they may provide a major opportunity for cost savings as defense budgets decline. At the same time, the behavior of indirect costs has a significant effect on the process of cost estimating. A thorough understanding of indirect costs allows us to make better projections of the effects of program reductions and extensions.

IDA has assisted OSD in collecting cost and business data from defense contractors for the purpose of developing statistical models to forecast indirect costs for new systems. During the 1980s, we completed 23 studies of 12 defense contractors. We are now updating the data and statistical models through 1993 for five major contractors, thereby incorporating experience from the recent downturn in defense procurement. The updated models will be used to forecast indirect costs for each of the contractors, and to partition indirect costs into fixed and variable components. The results of this effort will enable DoD to more accurately estimate the costs of new systems produced by these contractors.

Cost of Military Medical Care

In fiscal year 1985, medical expenditures accounted for about three percent of the DoD budget. By fiscal year 1992, the figure had grown to over five percent. Further growth is forecast in the future, as the retired military population continues to increase, more than offsetting reductions in the active duty force. In light of these trends, Congress mandated that DoD conduct a comprehensive study of the military medical care system. DoD asked IDA to provide analytical support to this study.

We first established a baseline medical expenditure of $16 billion for fiscal year 1990. This estimate is about 10 percent higher than previous official estimates, the difference being largely due to our detailed accounting of medical personnel assigned to combat and combat support units during peacetime. We also developed models that relate cost to workload for individual military hospitals. Finally, we used our models to project in-house medical costs under four policy options. These options involved expansion or contraction in system-wide capacity, corresponding changes in workload and, in a few instances, competition for enrollment of beneficiaries.

Software Development and Costing

Economic Benefits from Software Technologies

The Department of Defense may spend as much as ten percent of its budget on software. The Defense Information Systems Agency (DISA) is developing software engineering technologies that offer the potential to slow the rate of growth or even

reduce these expenditures. The technologies fall into three broad categories: software reuse, software engineering processes, and software engineering environments or tools. DISA asked IDA to estimate the likely payback to DoD from investments in these technologies, and to determine whether these investments are economically justified.

We are constructing a model to estimate the expected use of the new technologies throughout the DoD, and the likely savings that will result when these technologies are employed. For various reuse technologies, preliminary estimates indicate a benefit/cost ratio of six to one. These preliminary ratios are much smaller for software engineering processes and software engineering tools, though still greater than one to one. IDA is continuing this research to identify specific investments that yield the greatest financial payoff.

Megaprogramming

In the future, DoD expects some software systems to be assembled from reusable components, thus allowing development to proceed more quickly and predictably. The resulting software also should be more reliable than is current software, built from scratch. Software developers would select from libraries or repositories of software components and build the program "component-by-component," rather than the traditional method of writing program code "line-by-line." In addition to reuse, the DoD is encouraging employing more formal software engineering practices and better, more interoperable tools that partially automate software development and maintenance. The three areas of reuse, engineering practices, and automation tools are grouped under the title "megaprogramming."

The Advanced Research Projects Agency is conducting three software demonstration projects related to megaprogramming to improve understanding of the potential costs and benefits of employing these techniques throughout DoD. IDA has been asked to quantify the investment costs and benefits of megaprogramming as implemented by the demonstration projects. Although these demonstration projects will not be completed until the end of fiscal year 1995, preliminary analysis suggests that investments in megaprogramming may have significant payoff.

Manufacturing

Defense Manufacturing Strategy

The Department of Defense established the Defense Manufacturing Council (DMC) to develop an integrated, coordinated strategy for fielding affordable and technically superior weapons systems and to identify the resources and initiatives needed to implement this strategy. Numerous elements of DoD and industry will participate in the formulation of the strategy and recommendations for implementation.

IDA has been involved with the DMC since its inception. We provided early support by collecting and analyzing information on current initiatives for reducing manufacturing costs, both to document lessons learned from these initiatives and to identify gaps that could be exploited to further reduce costs. This work highlighted several elements that should be incorporated into the new manufacturing strategy. First, planners should use Integrated Product Process Development techniques to integrate all aspects of weapons systems development from the start of a program. Second, cost reduction measures are best introduced as pilot programs. And finally, cost reduction initiatives will be most effective if implemented by procurement executive officers and program managers. As the manufacturing strategy evolves, the focus of IDA's work will shift from strategy development to strategy implementation.

Agile Manufacturing

Agile manufacturing comprises a set of technologies and business practices designed to allow enterprises to respond quickly, efficiently, and effectively to new customer needs by shortening product cycles and allowing flexible production quantities. In environments of continuous and unanticipated change, agile manufacturing techniques are particularly advantageous. Such techniques may also facilitate DoD's objective of maintaining a strong defense industrial base through commercial, nonmilitary production.

The Advanced Research Projects Agency has asked IDA to assess the applicability of agile manufacturing techniques to military products. In particular, we are assessing the compatibility of agile manufacturing with the objectives of the Defense Manufacturing Council and the overall DoD Integrated Affordability Strategy.

DARPA Initiative in Concurrent Engineering (DICE)

The Department of Defense is always looking for ways to reduce the costs of weapons systems, shorten their development time, and improve their quality. In the mid-1980s, commercial companies began to report gains in these areas as a direct result of adopting a new approach to major product development — concurrent engineering. Concurrent engineering is a systematic approach to the integrated, parallel design of products and their related processes, including manufacture and support. It forces developers to consider from the outset all elements of the product life-cycle, from concept through disposal and including quality, cost, schedule, and user requirements.

In 1987, DARPA held a concurrent engineering conference to learn more about

the benefits gained by companies that had tried the approach. In response to subsequent Congressional direction, the DARPA Initiative in Concurrent Engineering (DICE) was established to develop, validate and disseminate related technologies. As a result of this five-year program, concurrent engineering technologies are being used in several defense programs.

IDA has supported DARPA (now ARPA) in providing direction and analytical support for the DICE program. We helped identify critical areas in which government-funded research could facilitate the use of concurrent engineering in the defense industry, and we helped evaluate contractor proposals for further technology development. When the DICE program recently concluded, IDA provided a comprehensive summary of the technical history of the program.

Commercial Electronic Component Use

The growth of the commercial electronics and computer industries has had a dramatic impact on the availability of integrated circuits and other electronic components for weapons systems. While DoD usage accounted for more than 75 percent of the US market for semiconductors in 1965, by 1995 the Department's usage is expected to be only about one percent of the market.

One result of this market evolution is that the most advanced integrated circuits are generally not those designed for a particular weapons system, but are those microprocessors, memories, or application-specific integrated circuits being manufactured in large quantities to meet commercial demands. Another result is that over the years, the highly competitive nature of the industry has developed commercial circuits with very high reliability. Even so, most commercial integrated circuits still do not meet the reliability requirements traditionally set by military specifications and standards.

Recent legislation and DoD directives are attempting to move away from traditional specifications that require specific materials and manufacturing processes toward specifications that are based on performance. IDA is supporting this effort by developing steps that DoD could follow to accelerate the use of commercial integrated circuits in military systems. The goal is to provide DoD with access to the most advanced component technology while taking advantage of the economies of scale that exist in commercial fabrication.

Acceptance Standards

For many years, DoD has relied on sampling inspection as the basis for acceptance of manufactured products. Sampling plans are selected based on Acceptable Quality Levels (AQLs), which index the principal military sampling standards cited in military specifications. This approach implies that DoD is willing to accept some level of defective product; as a result, suppliers are not driven to provide quality levels beyond that contained in the sampling plan. Recent demonstrated successes in obtaining quality products has led industry to shift its focus from defect detection through sampling to defect prevention through the control of manufacturing processes.

In FY1994, IDA completed a three-year study that resulted in a new DoD standard for product acceptance, based on statistical process control and the supplier's demonstrated quality program. This new standard will encourage continuous improvement of the supplier's manufacturing processes while protecting DoD from accepting defective products. Our work also complements efforts under way in DoD to reduce the paperwork associated with the acquisition process and to facilitate the use of commercially available products by using industry standards in place of those unique to DoD.

HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

IDA is a key component of the National Security Agency's research endeavor. For over 30 years, we have provided cutting-edge research in disciplines fundamental to the NSA mission, particularly mathematics and computer science. Reflecting changes in NSA needs and the state of computing more generally, the structure of the program has evolved into two separate, but interrelated, sets of activities.

Communications Research

The Centers for Communications Research in Princeton, New Jersey, and La Jolla, California, conduct mathematical research supporting the twin tasks facing the cryptologists of the NSA: cryptography and cryptanalysis. Mathematics remains the fundamental science used in the creation and analysis of the complex algorithms used to encipher vulnerable communications. As the modes and means of modern communications became more complex, the NSA asked that the Centers expand their research into other areas, to include speech and signals analysis.

In support of mathematics research, the Centers have placed increasing emphasis on computation. Beginning with their acquisition of a CDC 1604 in 1960, CCR researchers have become leaders in anticipating and exploiting the synergy between pure, theoretical mathematics and the science of computation.

In the spring of 1994, IDA installed a new, state-of-the-art, massively parallel Cray Research T3D supercomputer for use by its three Centers supporting the NSA. This architecture has great potential for NSA applications, but also presents significant challenges. In order to better understand these capabilities and challenges, the Center for Communications Research in Princeton and the Center for Computing Sciences in Bowie, Maryland, hosted special summer study programs. Approximately twenty academic mathematicians, ranging from senior research professors to several exceptionally talented undergraduates, joined with the regular research staff and a number of NSA mathematicians in Princeton to try to push the T3D to its limits. An additional twenty-five participated at the Center for Computing Sciences. The results of this study will help IDA and NSA mathematicians more effectively bring massively parallel computational technology to bear on NSA problems.

Computing Research

At the request of the NSA, IDA created the Supercomputing Research Center (SRC) in 1985. As computing has evolved, the Center's mission has expanded. In recognition of this, its name has been changed to the Center for Computing Sciences (CCS). CCS's mission is to focus the skills and talents of computer scientists, engineers, and mathematicians on exploiting the potential of high-performance computing techniques, including parallel processing, to solve intelligence-related problems of importance to the national security. Of necessity, specific details of the work of CCS are classified. However, general technology issues facing the entire High Performance Computing community can be discussed. Indeed, initiating such discussions is an important part of CCS's mission.

"Computational Science and Engineering" is a generic descriptive term for the research of CCS. CCS is active in devising algorithms suitable for parallel architectures. This entails research in computational aspects of selected areas of pure and applied mathematics. There are several efforts in the design of programming models and languages, and exploration of new architectural approaches based on very advanced technologies. CCS is also addressing issues in distributed computing, including bandwidth, cost, and robustness.

The aggregate total of CPU power and memory that advanced parallel machines offer could make them an important tool for quickly generating the raw material for producing timely intelligence. However, in many settings, only part of the potential of parallel machines has been realized because of the difficulties of making effective use of massive parallelism. Use of parallel architectures should be productive,

efficient, and cost-effective. In concrete terms, this means:

- parallel machines should provide access to solutions unobtainable by other means;
- arriving at solutions must not require a superhuman effort; and
- the costs of machines must satisfy the constraints imposed by shrinking budgets.

The following paragraphs offer brief descriptions of projects that address each of these three requirements.

An All-Optical Network

To achieve solutions unobtainable with prior technologies, parallel computers will need to run at teraflop rates. At this time, there are still two significant barriers preventing massively parallel supercomputer applications from running at these speeds: inadequate network speeds (called bandwidth) and the scarcity of software to aid in parallelizing applications. Recent work at CCS relating to an all-optical network promises to solve the first problem, while its development of improved parallel languages addresses the second.

In the proposed all-optical network, data moving through the network is broken into discrete chunks consisting of a message and a header. Both the message and the header are processed optically. In order to accomplish this, it was necessary to invent a network topology that allows implementation of a radically new control logic having the property that all routing decisions are based on examination of only a single bit of header.

Parallel Languages

Some of the large-scale computations required for NSA applications are, in fact, very good candidates for implementation on parallel machines. However, the style of computing required is quite different from that used in much scientific computing, because the amount of communication among processors is very large and does not follow any pre-determined pattern. Instead, extensive and unpredictable communication among processors is the norm. Therefore, memory must look "flat" from the point of view of the programmer who is developing applications and waiting for the results of computations.

AC is a language designed to implement MIMD programming for a large class of vector and/or parallel architectures. AC is a modification of ANSI-C that avoids forcing any particular high-level parallel model of computation on the user. One significant advantage of this approach is that AC is used effectively to program high performance subroutines that can be called directly from a high-level programming model.

IDA first used AC on the CM-5, a large parallel computer from Thinking Machines Corporation. It was distributed to ten CM-5 sites including the largest installed systems at the University of Minnesota and Los Alamos National Laboratory. More recently, a version of AC for the T3D built by Cray Research has been developed. Because the T3D provides high bandwidth between processor nodes, the new version of AC allows extensive use of message passing under control of the programmer. Initial experiences during last summer's work on the T3D were very encouraging, and more recently, there have been some dramatic successes.

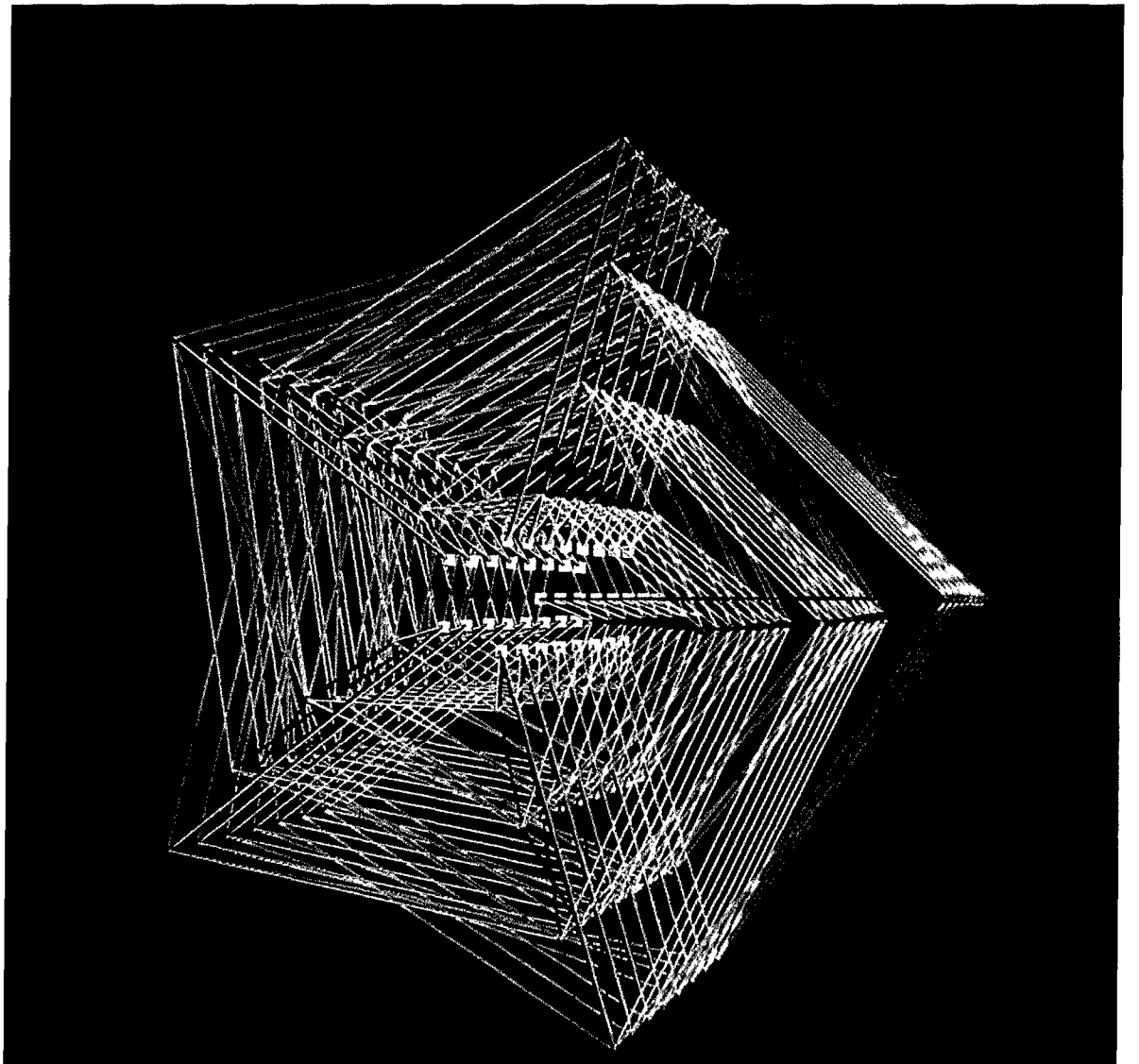
Custom Computing

For certain applications, specialized machines and "custom computing" can provide enormous power at a modest cost. Splash 2, designed and built at CCS as an attached processor for work-stations, exploits parallelism at several levels. In part, its design was motivated by CCS's earlier work on "systolic arrays," but Splash 2 is unusual because its processors are Field-Programmable Gate Arrays (FPGAs). FPGAs are semiconductor chips for which users can design or program applications. Once designed, the FPGAs behave like custom hardware circuitry, hence the high performance. Unlike special-purpose systolic array hardware, the FPGAs can be reprogrammed as often as desired.

Providing a Splash 2 system to several research groups is part of CCS's broad effort to transfer its FPGA expertise to US users outside the DoD. CCS collaborated with

researchers at seven universities throughout the United States, providing access to the Splash 2 hardware and software resources. CCS was also one of the two organizers of the first IEEE Workshop on FPGAs for Custom Computing Machines, a meeting which brought together 125 representatives of academia, business, government, and industry to explore this new development in computing technology.

This technology has been successfully transferred to the private sector. Having licensed the technology from NSA and CCS, two private companies are now commercializing systems based on the Splash design.



A multiple level minimum logic network

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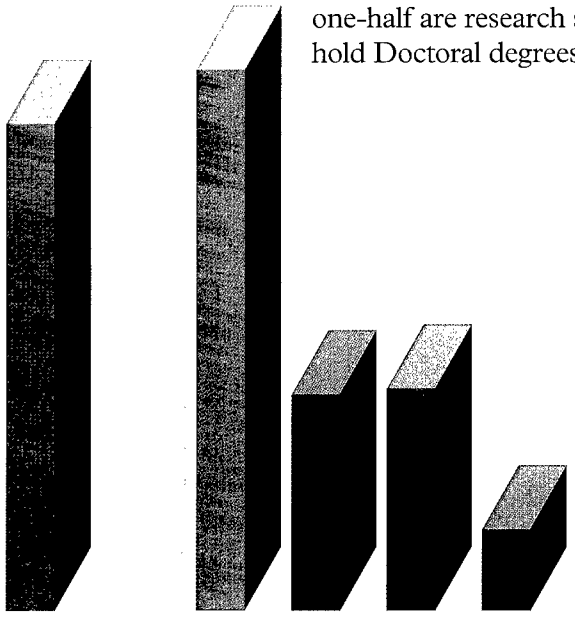
As of February 1995, the IDA staff numbered 820, of whom approximately one-half are research staff members. Among the research staff, 61.4 percent hold Doctoral degrees, an additional 29.3 percent hold Masters degrees.



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The Centers for Communications Research conduct fundamental research supporting the National Security Agency in cryptology, including the creation and analysis of complex encipherment algorithms, as well as speech and signal analyses.

Center for Computing Sciences

Dr. Francis Sullivan, Director

The Center for Computing Sciences conducts research supporting the National Security Agency in many disciplines of computational science and engineering, including computational algorithms and methods, computer architectures, parallel processing, applications of computing to various aspects of mathematics and applications of mathematics to computational issues.

Computer and Software Engineering Division

Dr. Richard J. Ivanetich, Director

The Computer and Software Engineering Division conducts analyses and assesses the application of advanced computing systems and information technologies. The research program also addresses the development of advanced computational techniques and their operational application as prototype systems.

Cost Analysis and Research Division

Dr. Stephen J. Balut, Director

The Cost Analysis and Research Division collects, analyzes and estimates the full life-cycle costs of acquiring and operating forces, systems and components. The division also creates new or improved methodologies and computer-based models for cost estimation, frequently pushing the state of the art.

Operational Evaluation Division

Mr. Thomas P. Christie, Director

The Operational Evaluation Division supports the Office of the Secretary of Defense in the planning and evaluation of Service operational tests of major new weapon systems, and in the observation and evaluation of Live Fire Tests of the lethality and vulnerability of weapons and platforms. The division also supports the Joint Staff and Combatant Commands in analyzing military operations and in developing, integrating and improving the mission planning process.

Science and Technology Division

Dr. Lemmuel L. Hill, Director

The Science and Technology Division investigates and models scientific phenomena and conducts technical characterizations and evaluations of devices and systems, the media in which they operate, the targets they engage, and/or the missions they perform. The division also conducts technology assessments critical to research and development programs, acquisition decisions, and technology planning.

Strategy, Forces and Resources Division

Mr. Christopher Jehn, Director

The Strategy, Forces and Resources Division performs integrated, interdisciplinary studies of defense planning and policy related to national security strategy, structure and capabilities of US and foreign forces, and infrastructure supporting US forces.

System Evaluation Division

Dr. David L. Randall, Director

The System Evaluation Division analyzes the potential performance, technological risks and costs of systems proposed or in development, typically in support of acquisition decisions. The division also recommends ways to maximize system cost-effectiveness and flexibility and to minimize system vulnerabilities.

Simulation Center

Mr. L. Neale Cosby, Manager

The Simulation Center supports the six Virginia-based IDA research divisions in developing and applying advanced distributed simulation to defense analyses. It also provides a DoD-wide forum for demonstrating new simulation technologies and for educating potential users in the capabilities of advanced distributed simulation. The Center is a Washington node for the Defense Simulation Internet, thereby connecting IDA with other simulation facilities across the country and overseas.

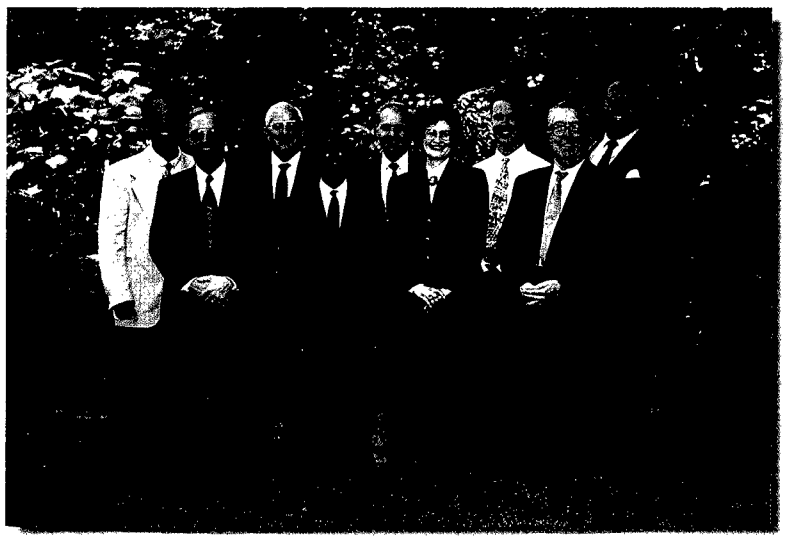
AWARDS FOR EXCELLENCE

IDA's ability to fulfill its mission depends on the intelligence, expertise and perseverance of its people. To underscore the Institute's dedication to excellence at all levels of the organization, IDA annually presents awards to staff members whose work, either over time or on particular projects, has been exceptional.

The Andrew J. Goodpaster Award for Excellence in Research for 1994 was presented to *Dr. Benjamin W. Turner* of the Operational Evaluation Division. Dr. Turner has distinguished himself as an analyst and researcher and has become a preeminent expert in the fields of combat vehicle vulnerability and weapons system lethality. He has made major contributions to the OSD Live Fire Test program and has been the dominant force in the analysis and reporting of numerous test programs for the Director of Test and Evaluation, OUSD(A&T). Dr. Turner completed a major evaluation of the vulnerability of the M1A2 Abrams Main Battle Tank and a companion study of the validity of using the Army's SQUASH combat vehicle vulnerability model to support Live Fire Test & Evaluation programs. The final report to Congress on the M1A2 Live Fire T&E program was accurate, well conceived, innovative, and clearly communicated. Dr. Turner exemplifies a level of excellence that epitomizes the role of the IDA analyst as a unique asset supporting the Office of the Secretary of Defense.

The W. Y. Smith Award for Excellence, designed to recognize outstanding contributions by non-research professionals, went to *Arthur L. House* of the Science and Technology Division. As STD's Administrative Officer, Mr. House is responsible for all administrative matters within the Division, including preparation of the program plan and budget, task order processing, financial execution, computer requirements and support, subcontracts, interactions with other administrative elements of IDA as well as Division staff, and security. His excellent organizational, managerial and interpersonal skills have earned him this recognition, as well as the respect of his colleagues throughout IDA.

The IDA President's Award for Excellence was established to recognize and reward support staff members who have made significant contributions to the Institute's success. This year, awards were presented to *Mr. James E. Jackson* and *Ms. Peggy L. White* of Administrative Services at IDA-Virginia, and the Facilities Staff team of *Kenneth Adams, Donald Long, Steven Douglas, John Donovan* and *Jerry Palla* at the Center for Computing Sciences.



1994 Awards for Excellence were presented to, from left to right: Kenneth Adams, Benjamin Turner, Arthur House, Steven Douglas, Jerry Palla, Peggy White, Donald Long, John Donovan, and James Jackson.

OUTREACH

To maintain IDA as a center of excellence, we support a number of programs that help our staff stay current both in their disciplines and on changes in the external environment that should inform their work. We also accept a responsibility to help nurture future generations of defense analysts and citizens. The programs below represent the Institute's efforts to meet these multiple challenges.

Colloquia and Symposia

IDA Speakers Program

In addition to technical seminars held by the individual research divisions, IDA hosts a rich diversity of outside speakers. A sampling of our guests, with their affiliation at the time of the presentation, illustrates the breadth of issues and perspectives represented.

Dr. A. J. Bacevich, Executive Director, The Foreign Policy Institute, The Paul H. Nitze School of Advanced International Studies, The Johns Hopkins University
Two Cheers for Isolationism

Ms. Marjory S. Blumenthal, Executive Director, Computer Science & Telecommunications Board (CSTB), National Research Council
Realizing the Information Future: The National Research Council Report on the Future of Internet

Dr. David Chu, Senior Fellow, The RAND Corporation
Our Changing Defense Posture: Contrasting the Clinton and Reagan/Bush Approaches to National Security

Dr. Sidney D. Drell, Professor and Deputy Director, Stanford Linear Accelerator Center, Stanford University
Reducing Nuclear Danger in the Post-Cold War World

Mr. Edwin Dorn, Under Secretary of Defense for Personnel and Readiness
Challenges in Personnel and Readiness

Mr. Lawrence S. Eagleburger, Senior Policy Advisor, Baker, Worthington, Crossley, Stansberry & Woolf
Foreign Policy in the 1990s

Dr. Burton I. Edelson, Director, Institute for Applied Space Research George Washington University *New Developments in Global Communications Technology*

Dr. Edward A. Feigenbaum, Chief Scientist, U.S. Air Force and Professor of Computer Science, Stanford University
The US and Japanese Software Products Industries: Success Factors in an Era of Rapid Change

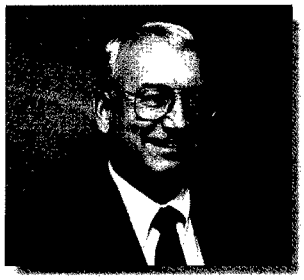
Rear Admiral Nick Gee, U.S. Navy (Retired), Former Commander, Joint Task Force Four
National Counterdrug Operations and Policy

Dr. Gerald Hane, House Committee on Sciences, Space and Technology Subcommittee on Technology, Environment and Aviation
R&D Consortia as Innovation Strategies: Contrasting the US and Japan

Dr. Seigfried S. Hecker, Director, Los Alamos National Laboratory
The Future of National Laboratories in Science and Technology

Mr. Dan C. Heinemeier, Vice President, Government Division, Electronic Industries Association (EIA)
EIA Views on Defense Conversion Programs

Dr. Paul G. Kaminski, Chairman, Defense Science Board, Chairman and Chief Executive Officer, Technology Strategies & Alliances
Issues of Current Interest to OSD as Seen by the Chairman of the DSB



Mr. John N. McMahon, President and Chief Executive Officer, Lockheed Missiles & Space Company
The Evolving Role of Space in National and Economic Security

Dr. Joseph S. Nye, Chairman, National Intelligence Council
Intelligence Estimates after the Cold War

Dr. Stanley Orman, Chief Executive Officer, GTS Inc., formerly Director General, UK SDI Participation Office
The Role of Theater Missile Defense in the New World Order

Ms. Colleen A. Preston, Deputy Under Secretary of Defense for Acquisition Reform *Acquisition Reform*

Dr. Victor H. Reis, Assistant Secretary for Defense Programs, U.S. Department of Energy
Science-Based Stockpile Stewardship

Dr. Daniel Roos, Professor of Civil Engineering, Massachusetts Institute of Technology
Lean and Agile Manufacturing: Reflections on Changing Paradigms

Colonel David M. Sa'adah, Special Assistant to the Program Manager, Combat Identification, Intelligence and Electronic Warfare, U.S. Army
Friendly Fire: How it has been Measured and with what Consequences?

Dr. R. D. Shelton, Director, International Technology Research Institute, Loyola College
International Technology Assessments

Mr. Gary D. Vest, Principal Assistant Deputy Under Secretary of Defense (Environmental Security)
The DoD Environmental Security, Safety and Occupational Health Program

Ms. Emily Willey, Director of Market Requirements and Government Relations, Honeywell, and Chair, Government Division Requirements Council, Electronics Industry Association (EIA)
EIA Ten-Year Forecast of Defense, NASA and Related Market Opportunities

Education Programs

A vital research community such as IDA's depends on the educational community for its strength and shares some of the responsibility for its health. This mutually supportive relationship is the basis for IDA's educational activities.

Over the years, IDA has looked to the academic community to help satisfy our need for a continual infusion of new ideas, state-of-the-art techniques and access to the most talented academic researchers. We thus seek strong ties to, and cooperative activities with, the academic community where these ties and activities are consistent

with the needs of IDA's Divisions and support our national security mission. Principal educational components of the Outreach program during 1994 were the continuing Defense Science Study Group program, a special symposium for DSSG alumni, a newly revitalized summer intern program, and continuing programs in cost analysis with George Mason University.

The Defense Science Study Group

The DSSG program is one of education and study, with emphasis on research and development in DoD and on the capabilities and operations of the military. Begun in 1985, the DSSG helps foster a long-term, informed interest in national security issues among successive new generations of university leaders in science and technology. The members are young professors of science and engineering who are widely recognized in their academic fields. The 17 members of the fourth class of the DSSG, begun in early 1994, represent 14 universities and nine different academic disciplines. During the first year of this two-year course, the members received briefings on the principal institutional players — both civil and military, congressional and executive — in defense matters. Their summer program included visits to the aerospace companies and to military facilities. During many of these visits, the members were accompanied by several senior mentors and former military officers, including General Larry Welch, General W. Y. Smith, Admiral Harry Train, and General Alfred Gray.

Symposium on Parallel Computing

IDA convened a three-day symposium on "Applications of New Computational Methods to Defense Science and Engineering," the theme of which was suggested by the DDR&E, Dr. Anita K. Jones, who also served as keynote speaker. The goal was to have the DSSG alumni and several other key academics discuss their use of computational experimentation using parallel computers, focusing on possible defense applications. DoD and DoE scientists presented similar briefings related to their research. Much of the discussion centered around the use of massively parallel computing in areas such as nuclear weapons, information technology/signal processing, simulation-based design, materials processing, computational fluid dynamics, and automatic target recognition.

DSSG members exchanging ideas with Secretary Perry

Summer Intern Program

This year, the Institute ran a summer intern program for 25 top graduate and undergraduate students. The interns worked hand-in-hand in IDA's Virginia Divisions with members of the research staff, who served as mentors.

In addition to their research activities, these men and women participated in educational events which included an introduction to IDA and DoD and a visit to the Pentagon. They organized a research day at the beginning of August to present the results of their summer work to each other and interested IDA staff. Many of this year's interns are likely to return to national security issues, and perhaps to IDA, in the future.

Cooperative Activities in Cost Analysis

IDA continues to participate in two programs developed to share our expertise in cost research for defense applications with the broader cost analysis community.

At George Mason University, IDA researchers teach a graduate, for-credit course focusing on the correct application of existing methods as well as the development of new methods. Because many of the students are already working in the cost analysis area — either directly with DoD or for contractors providing cost analysis to DoD — the potential is high for improving capabilities within the defense cost analysis community, thereby improving cost estimates of future defense systems.

IDA also continues to conduct cost research symposia in cooperation with the Cost Analysis Improvement Group (CAIG) in the Office of the Secretary of Defense. In conjunction with annual symposia, cost research projects being conducted by DoD offices, FFRDCs, and universities are catalogued to provide a baseline for planning future DoD cost research, and to facilitate exchange of findings and data. These symposia benefit the government through cost savings — for example, avoidance of wasteful, unnecessary duplication of effort; joint funding of projects of mutual interest — and increased productivity — for example, sharing of findings and data allows more time for estimating and less need for data collection.

Community Volunteers

For IDA to provide financial support to an outreach activity, there must be a clear nexus between that activity and the Institute's primary mission of supporting national security decision making. We can and do, however, encourage and provide opportunities for our employees to volunteer their time to develop America's youth.

Explorer Post

The Boy Scouts of America have been a major part of the lives of many of the youth in this country for over 80 years. In order to promote the goals of citizenship, service and duty espoused by the Boy Scouts, IDA sponsors an Explorer Post to help interested youth gain knowledge about possible careers in computer science and the other scientific disciplines represented by the IDA staff. Over 30 members of the IDA research community have volunteered their time and effort for this worthy undertaking.

Local Schools

As one of the largest private employers in the city of Alexandria, Virginia, IDA has a concentration of talents and capabilities that few organizations can rival. Recognizing the continuing need to improve this country's educational content and processes, particularly in science, mathematics and technology, IDA actively encourages its staff to help local school systems, on a voluntary basis, to raise the academic performance of students in elementary, junior high and high school, improve teacher training, and act as advisors on curriculum development. To this end, discussions with the Alexandria School Board are ongoing to explore the areas where IDA can make the greatest local impact in pre-college education.

FINANCIAL REPORT

BALANCE SHEETS

September 30, 1994 and September 24, 1993

	1994	1993
	Assets	
Current assets:		
Cash and cash equivalents	$ 8,808,039	$ 13,233,591
Contract receivables	14,156,316	12,321,300
Prepaid expenses	444,375	586,254
Total current assets	23,408,730	26,141,145
Prepaid bond interest, less current portion	157,482	171,504
Prepaid ground rent, less current portion	1,111,800	1,133,600
Property, plant and equipment - net	25,164,353	26,328,118
Other assets	45,346	71,999
Total assets	$49,887,711	$53,846,366
	Liabilities	
Current liabilities:		
Current portion of long-term debt	$ 774,155	$ 774,155
Accounts payable and accrued expenses	4,884,400	6,535,813
Accrued annual leave	3,557,356	3,488,776
Accrued pension costs	100,000	195,454
Accrued post-retirement benefits costs	545,000	-
Total current liabilities	9,860,911	10,994,198
Long-term debt, less current portion	7,950,565	11,754,721
Total Liabilities	17,811,476	22,748,919
Commitments and Contingencies		
	Corporate Equity	
Corporate Equity	32,076,235	31,097,447
Total liabilities and corporate equity	$49,887,711	$53,846,366

The Institute's audited financial statements are available from the Treasurer on request.

STATEMENTS OF REVENUE AND EXPENSES AND CHANGE IN CORPORATE EQUITY

for the years ended September 30, 1994 and September 24, 1993

	1994	1993
Revenue:		
Contract revenue, including fixed fees of $5,031,347 and $4,911,045, respectively	$107,264,165	$105,109,217
Program expenses:		
Charged to US Government contracts:		
Direct salaries	49,887,728	47,853,384
Other direct costs	29,272,033	30,166,894
Indirect costs	22,949,262	23,412,736
	102,109,023	101,433,014
Charged to Institute projects:		
Direct salaries	1,117,430	576,489
Other direct costs	1,254,736	1,364,348
Indirect costs	1,563,161	1,140,560
	3,935,327	3,081,397
Total program expenses	106,044,350	104,514,411
	1,219,815	594,806
Interest income	270,173	336,514
Bond arbitrage rebate	(22,200)	-
	247,973	336,514
Excess of revenue over program expenses before cumulative effect of change in accounting principle	1,467,788	931,320
Cumulative effect of change in accounting principle	(489,000)	-
Excess of revenue over program expenses	978,788	931,320
Corporate equity:		
Beginning of year	31,097,447	30,166,127
End of year	$32,076,235	$31,097,447

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SPONSORS

Office of the Secretary of Defense

Under Secretary of Defense, Acquisition and Technology
- Director, Defense Research and Engineering
- Assistant to the Secretary of Defense, Atomic Energy
- Assistant Secretary of Defense, Economic Security
- Principal Deputy Assistant Secretary of Defense, Dual Use Technology & International Programs
- Deputy Under Secretary of Defense, Environmental Security
- Deputy Under Secretary of Defense, Logistics
- Deputy Under Secretary of Defense, Advanced Technology
- Director, Acquisition Program Integration
- Director, Strategic and Tactical Systems
- Director, Test Systems Engineering and Evaluation
- Director, Defense Modeling and Simulation

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- Assistant Secretary of Defense, Strategy & Requirements
- Assistant Secretary of Defense, Counterproliferation Policy
- Assistant Secretary of Defense, Special Operations & Low Intensity Conflict
- Director, Net Assessment

Under Secretary of Defense, Personnel and Readiness
- Assistant Secretary of Defense, Health Affairs
- Assistant Secretary of Defense, Force Management Policy
- Deputy Under Secretary of Defense, Readiness

Assistant Secretary of Defense, Command, Control, Communications & Intelligence
Director, Program Analysis and Evaluation
Director, Operational Test and Evaluation
Commission on Roles and Missions of the Armed Forces

Joint Staff and Commands

Defense Agencies

Advanced Research Projects Agency
Ballistic Missile Defense Organization
Defense Information Systems Agency
Defense Nuclear Agency
National Security Agency

Other Federal Agencies

National Aeronautics and Space Administration
Department of Energy
Department of Transportation
United States Coast Guard